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STUDY ON IRRIGATION SYSTEMS REHABILITATION AND IMPROVED OPERATIONS AND MANAGEMENT

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ACTIVITY A: REHABILITATION AND IMPROVEMENT FOR MANAGEMENT

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EXECUTIVE SUMMARY

Improvement in Plain System Management has been identified as a key to better performance of irrigation systems. This aspect of Irrigation Management deserves more professional attention and research.

The objective of the present study is to document with a management-oriented approach the reality of main canal operations with particular reference to the implications of the planning and design of main systems on the management and performance of the systems. Main canal regulation has been analyzed from the point of view of (a) its impact on the distribution of flows from the main canal, (b) its contribution to the manageability and ability to operate the physics1 systems, and (c) its implications for the managerial requirements of the irrigation agencies.

IIMI has conducted a compsrative study of three irrigation systems in Sri Lanka and one in the Philippines, which display different planning and design features in their main systems and canals. These are: (a) the Kalankuttiya Branch Canal of the Galnewa Project in System H of the Mahaweli Economic Agency of the Mahaweli Authority of Sri Lanka; (b) the Right Bank Main Canal (RBMC) of the Kirindi Oya Irrigation and Settlement Project (KOISP) of the Irrieation Department, Sri Lanka; (c) the Rajangana Pilot Distributary Canal of the Rajangana Irrigation Scheme of the Irrigation Department, Sri Lanka; and (d) the Santo Domingo Area (SDA) Plain Canal of the Upper Pampanga River Integrated Irrigation System (UPRIIS) of the National Irrigation Administration (NIA) of the Philippines.

The study analyzes the impact of the physical aspects of the systems, including the structuring of main systems and canals, on (a) the organizational setup of the Irrigation Agencies in charge of their operations, and (b) the manageability of the two interrelated primary functions of a main canal, namely the <u>conveyance</u> of water from a source of supply to remote places of <u>delivery</u> to sub-units of the system.

Field investigations and analyses have been conducted to examine (a) the actual conditions under which canal operators exert control over the <u>physical process</u>. the flow of water, and (b) the actual conditions under which the <u>management process</u> of decision making takes place at the various operational levels of the agency as required for <u>canal regulati</u>on.

Most of the information utilized for the study was collected during one irrigation season in 1988. This was performed through (a) intensive automatic recording of canal water levels using electronic data-longer technology, as well as classical stare-recorders (a total of 31 different. sensing points were dispersed at key locations alone the main canals and at some branching points), (b) careful field monitoring of canal operations, and (c) interviews of the operations staff. The study also drew upon previous work conducted by IIMI on the same systems as well as results generated by simulations performed through available mathematical models of some of the canals.

A. The Impact of Planning and Design on the Management of the Conveyance of Water in the Main Canals Studied

The main. canals studied correspond to subsystems of much larger projects. With the exception of the Kirindi Oya Right Bank Main Canal, which takes off directly from a main storage reservoir, the canals studied were dependent for their supply on an upper conveyance system. In the case of the Kalankuttiya Branch Canal, the upper conveyance system consists of a cascade of 3 tanks, namely, Kalankuttiya, Mulannatuwa, and Kalawewa. The last tank is itself supplemented by a diversion from the Mahaweli River. In the case of the Santo Domingo Area Main canal, the upper conveyance system is characterized by a cascade of 5 diversions along the 50 km long water course and diversion canal (DC#1) between the source of supply and the head of the canal studied (SDA Main Canal). In the case of Rajangana the canal studied is a distributary canal taking off the upper reaches of a main canal.

The following design characteristics were identified as important parameters that constitute the foundation for more decentralized operations at the head of subsystems:

A1. Decentralized storage capacities such as in Mahaweli System H can improve the manageability of extended systems. This was evidenced by the higher level of performance achieved in System H, in terms of the quantitative control of the supply at the head of the subsystem, when compared with the Diversion Canal DC#1 at UPRIIS.

At Kalankuttiya, during yala (dry season) 1988 the management of the left bank main canal (conveyance system) succeeded, with limited managerial effort, in refilling the Kalankuttiya Tank in due. time without affecting the program of water issues from the tank. This result, however, has to be weighed against the difficulties experienced previously at a time of water shortage (maha, or wet season, 1986/87). This shortage put exceptional strain on the conveyance system and on its management, which found itself relatively unprepared to face such a situation with its usual managerial practices.

At the UPRIIS, on the contrary, the supply provided at the head of the SDA Main Canal depends largely on the performance of the upper conveyance system (DC#1). In 1988, the supply at the head of the SDA was very irregular despite the considerable managerial efforts deployed by the staff of the Water Central Coordinating Center of the UPRIIS/NIA, assisted by the District Hydrologist and supported by an effective radio communication system. The supply conditions at the head of the system make it almost futile for the Agency to envisage distributing water within the Santo Domingo Area with the objective of quantitative flow control as in the case of Kalankuttiya. Instead, it was observed that the distribution was implemented with a rather high degree of success on the basis of a "degraded" objective, that, is, to share whatever inflow is available in proportion to the planted areas.

A2. The rational use of hydraulic "controls" (e.g., long-crested weirs) across canals, if permitted by the topography, as an alternative option to manual water level control through gated cross-regulators, was found to have a significant impact on the staffing. and manageability of the systems. Reasons for this include: (a) simple hydraulics and simple operations; (b) reduced room for decision making at the level .of the operators while nevertheless improving the quality of the water level control in the main canal, which in turn conditions the decision making and operations at the offtakes aimed at flow control; (c) opportunity for decentralized operations of the delivery function, relatively uninfluenced by the operations related to the conveyance of water in the main canal.

It was observed,' in Kirindi Oya, that the excessive operational flexibility available at the diversion point from a main canal (gated cross-regulator plus lateral offtake) was abused to the detriment of conditions for effective management of the conveyance of water throughout the main canal. A likely explanation is that the present concern of gate operators is limited to the distribution of water; they have little or no concern for the conveyance of water along the main canal.

It was also observed that although "controls" are seldom used as level control devices, they are more readily used as measuring devices, but sometimes with limited success.

"Controls" in the form of duckbill weirs existing at the Kalankuttiya Branch Canal, (and on the Rajangana Pilot canal) were found to be effective in creating hydraulic conditions (control of level) suitable for the control of water issues at the offtakes while eliminating the burden of gate operations on the main canal and all its 'negative consequences. Under such a conditioning environment in the main canal, further gain of performance in the control of flow could be envisaged through technological innovations such as baffle distributors, provided of course that the process of technology transfer has been adequately effected.

B. Performance of the Conveyance System: A Conditioning Factor for the Control of Water Delivery

The planning and design features referred to above were found to have an impact on the performance of the conveyance of water along canals, a factor that conditions the control of the water delivery. Other managerial conditions required for the control of water issues that were examined were: (a) the availability of explicit delivery targets, (b) the possibility of obtaining feedback on the actual flows delivered, and (c) the availability of physical means for operations.

B1. At the head of the canals studied, these conditions were generally found to be adequate, with the exception of the SDA. The poor performance of the SDA b i n canal in that respect was essentially conditioned by the inadequately regulated sources of its supply: (a) the local flow from a creek, and (b) the irregular supply from the upper conveyance system. As a result, the delivery objective within the Santo Domingo Area during the 1988 wet season (which in fact turned out to be relatively water short) was found to be limited to the equitable sharing of available water and apparently not the provision of controlled water issues like in the other systems.

02. The general observation in the systems studied was that the managerial conditions required for the control of delivery at the offtakes were deficient. This deficiency can be attributed in part to the design features of the canals that' often include ineffective devices to assess the flow diverted. Of more importance, however, are the deficiencies of the present regulating mechanisms for the conveyance of water along the canals and the difficulties in achieving this with the current practices of operation of the gated cross-regulators, This gap was of particular significance at Kirindi Oya Right Bank Main Canal, as the hydraulics and the length of the canal make it difficult to perform efficiently the downstream mode of regulation attempted by the Agency. But even in the Rajangana Pilot Distributary Canal where this function could have been performed more easily, the Agency did not seem to have taken advantage of the technology to manage the conveyance function better, and in particular to monitor the inflow-outflow water balance along the canal.

C. General Findings and Conclusions

As a result of the investigations carried out in the four systems, some general conclusions were arrived at as follows:

C1. The territorial magnitude of extensive irrigation projects is reflected in the dimensions of the organizational setup of their management agencies.

C2. The potential complexity of the management is not only determined by the size and structure of the organizations but also to a large extent by the layout of the main system and' the hydraulics of the canals. It may also happen, however, that even in a system of limited size with an organization of corresponding magnitude, such as the Kirindi Oya Right Bank Main Canal, the canal hydraulics might still be highly complex. Appropriate managerial practices are therefore needed to cope with this complexity. The operation of systems in a dynamic manner while maintaining the objective of an acceptable level of performance generally results in a higher degree of complexity of the management.

C3. There are both a parallel and a link between the physical infrastructure of the irrigation main system and the superimposed organizational arrangements of the agency to manage tie water from the source to the various points of delivery.

C4. The parallel refers to the relative degrees of centralization versus decentralization available in both the agency and the physical system to control the complex process of decision making and the actions to be performed at various hierarchical levels with a view to the effective conveyance and distribution of water. The conveyance system of the Mahaweli System H, including a cascade of intermediate storage tanks, is an example of a main system with opportunities for decentralized operations of subsystems. In contrast, the conveyance system that provides the supply to the Santo Domingo Area Main Canal is directly dependent on the operations of a central reservoir.

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C5. The link refers to the opportunities provided, through the layout of the system and the characteristics of its hydraulic structures, for more or less decentralized operations. i.e., the degree of freedom available to an operator to make decisions in operating his subsystem, within certain limits, without being constrained by the operations of the higher order system and without interfering with it.

CG. One can expect the conveyance function to be the primary concern of the management level concerned with the operations of main canals over long distances. On the other hand, the delivery function is more likely to be the concern of the operators at. the offtakes. The design and operational practices of agencies, however, appear to lack a clear perception of these two interrelated functions of a main canal. The main canal tends to be perceived by irrigation agencies and their staff as a distribution system with .emphasis placed on the delivery aspects. Staff do not often take explicit account of the conveyance function in the normal operations of main canals. A rational approach to the management of the dynamics of the water transfer is not present.

C7. A rational approach to management should originate at the planning and design stage with a clear recognition of:' (a) the physical processes to be handled (conveyance and delivery); (b) the conditions which are favorable or not to the effective control of these processes (availability of effective means for intervention, availability of means of feedback regarding the ongoing processes); and (c) the constraints placed on the management of each process by one another if performed simultaneously in the same canal.

The degree to which the planning and design have provided the structural conditions for decentralized operation of the delivery function was found to be an important factor affecting the manageability of the system.

D. Recommendations for Improving Canal Regulation

D1. From these observations, it is clear that planning and design play a critical role in determining the complexity of the management of the conveyance of water along canals. The management of the conveyance function tends to have been neglected in the design of main canals. This is related to the assumption that main canals would usually operate under steady flow conditions. If this assumption were true the problem of regulating the conveyance would be eliminated. Observations, 'however, indicate that these conditions rarely exist in the canals studied. This problem is further aggravated when canal operations are expected to be more responsive to changes in agricultural water' demand as well as changes in the environment.

D2. Amongst the range of options available to an agency to improve the management of main canals in a dynamic situation, two directions have been identified; one dealing with improvements in the realm of Planning and Design, and the other with Management Improvements. These improvements, which could be achieved under a Rehabilitation and Modernization program, include the following:

1. Structural improvements through better Planning, Design, and Construction:

1.1. Structuring the main system in a functional way with due consideration for the primacy of the conveyance of water which has to be achieved through the main canal, and providing buffer capacity (intermediate storage, in-line canal storage, etc.) between the conveyance and distribution systems (but existing systems might have limited scope for such improvements).

1.2. Simplifying the hydraulics of canals and their structures through the rational use of hydraulic "controls" (weirs) to substitute for human control wherever permitted by the topography.

2. Managerial improvements through Organization Design and Information Communication:

2.1.. Structuring the organization in a functional manner, again recognizing the primacy of the conveyance function and providing the corresponding administratitve-managerial unit, appropriately located within the hierarchy of the agency, whose sole responsibility will be the operation of the conveyance system; the staff of this unit should be 'distinct from those engaged in operating the subsystems.

2.2. Coordinating and tightening the operations of structures along main canals through more integrated management at the main canal level; the ability to monitor, process, and communicate information in real-time between the operators and management is a key element; the widest possible range of management techniques and technology should be explored for this purpose :including both hardware and software options.

D3. Specific recommendations to cover both aspects (Hardware and Software) are outlined with respect to each of the four subsystems studied:

1. <u>Mahaweli System H - Kalawewa LB Plain Canal - Kalankuttiya Branch Canal</u>

1.1. Improving downward communication between the Mahaweli Authority of Sri Lanka (MASL), in Colombo, and the Project level at Galnewa.

1.2. Control of the distribution from the Kalawewa Left Bank Main Canal between Iialawewa Tank and Meegalewa Tank and regulation of the conveyance between tanks.

1.3. Regulation of the Kalankuttiya Branch Canal making use of water flow information at the tail end of the canal.

2. <u>Kirindi Oya Right Bank Main Canal (RBMC)</u>

2.1. Improve upward communication to the Water Management Feedback Center regarding progress of cultivation in the command area and rainfall, 2.2. Improve downward communication from the Headworks to the Resident Engineer, Right Bank.

2.3. Suppress the variability of flow associated with the maintenance of the syphon.

2.3. Improve the manageability of the RBMC: Develop a set of specific procedures for more effective operations of the main canal.

2.5. Improve the control of water issues at the offtakes.

2.6. Explore prospects to improve the regulation of the canal.

3. <u>UPRIIS - Diversion Canal DC#1 - Santo Domingo Area (SDA) Main Canal</u>

3.1. .Improve the control of water issues at the head of the SDA.

3.2. Improve the regulation of the water conveyance through the Diversion Canal DC#1.

3.3. Improve the distribution of water within the Santo Domingo Area.

4. <u>Rajangana Pilot Project</u>

4.1. Restore openness regarding the distribution of flow within the pilot area.

4.2. Reconsider the objective of a rotational mode of delivery in the pilot area.

4.3. Manage the transfer of technology.

Details regarding each of the above recommendations are described in the following section.

RECOMMENDATIONS

The conclusion of the present comparative study of the interactions between the design and the management of main systems, emphasized the need for improving performance of the regulation of the water conveyance through the main canal as a precondition toward the control of water issues, hence improving the manageability of the system with respect to this objective.

The importance of the basic concepts involved in canal regulation and their implications is not a discovery in itself, but the paradox is that they have not received enough professional attention and actual application.

Through the study, there have been opportunities to observe that even new irrigation projects planned and designed according to the latest design standard of agencies do not differentiate between the conveyance and distribution systems (Kirindi Oya); extensive main systems have sometimes no intermediate storage capacities and hydraulic control is minimized (UPRIIS); and key decision makers of agencies and designers still trust that 'the main canal operates under the prevailing steady flow conditions for which the canals have been designed. At the other end of the hierarchy, Irrigation Laborers rightly distrust measuring gages which frequently turn out to be submerged, and a plethora of gates often tends to substitute for the concept of flexible supply in a controlled manner - in others words, manageability. The rational approach to address the question of managing the dynamics of water transfer in a canal is generally not well perceived. Existing operational procedures to do this, if any, tend to let the operators manage the conveyance task (maintaining full supply depth, FSD, by standing order) and fail to consider that it is essentially an operational task for the intermediate level of decision making in a position to oversee a canal as a whole. The result is that the feedback provided to this level is often inadequate to serve for canal regulation. Finally, extensive and expensive projects financed by donors are designed in such a way that when the need arises to improve the regulation of flow, it is almost an impossible task unless there is dramatic upgrading of the managerial capacities of agencies.

With the growing concern to manage water resources more efficiently and to provide better water distribution services to fanners,,for diversified cropping in particular, the time is opportune to create more awareness amongst irrigation agencies and their staff regarding: (a) the concepts implied by Canal Regulation and the general principles to be applied; and (b) the changes to be introduced in the managerial practices of agencies as well as in the planning and design, of a nature to facilitate the subsequent operations of main systems with the objective of improving canal regulation.

This study is a modest contribution to that end. The reference to existing systems in Sri Lanka and the Philippines and to the actual operational practices of the agencies might help bring awareness amongst those agencies of the concepts associated with canal regulation. But the subject matter deserves a more comprehensive approach to transfer available knowledge and canal regulation technologies to their potential users.

The following is a list of specific areas identified for their potential to improve the manageability and the performance of the systems studied.[1] These are possible directions for further focused studies to improve rehabilitation and management of these systems.

Location-specific Recommendations

Mahaweli System H - Kalawewa LB Main Canal - Kalankuttiya Branch Canal

1. Downward communication between the Mahaweli Authority of Sri Lanka (MASL), Colombo, and the Galnewa Project level - The actual transfer of water diverted from Polgolla Dam to Kalawewa Dam is constrained by the priority usage of the Mahaweli River water for hydropower generation. As a result, the supply to Kalawewa is not fully predictable at the Project level and it does not tally with the Seasonal Operation Plan (SOP) which nevertheless is used by MEA for the postseasonal evaluation of the water management. This perturbs the planning of water allocations by the System H Water Management Panel, the formulation of targets for the water conveyance downstream, and finally, the distribution of water.

Contractual arrangement at the highest level between the two main users of the water - Power and Agriculture - at the onset of an irrigation season, updating information regarding the water resource availability, and communication by the MASL of this information to the Galnewa project level, would be conducive to optimal water allocations and achievement of targets with respect to the water distribution within Mahaweli System H. In any case, it would be advisable at the level of the System H Water Management Coordinating Panel to develop seasonal strategies for the use of Kalawewa Tank water for different scenarios of augmentation through Polgolla. This might lead to decisions regarding allocation of water from Kalawewa that may differ from the Seasonal Operation Plan established at the macro level by the MASL.

2. Control of the distribution from the Kalawewa Left Bank Main Canal (LBMC) between Kalawewa Tank and Meegalewa Tank and regulation of the conveyance between tanks - Inadequate control and supervision at the offtake to the Galnewa Block along the main canal jeopardizes the conveyance of water to the tank downstream. The operational and managerial capacity of the LBMC Unit would need to be strengthened with: (i) a Unit Head entrusted with a level of authority and seniority higher than the Irrigation Engineers of the blocks; (ii) adequate staff for operations and supervision at the offtakes; (iii) daily feedback regarding water levels of, and issues from, Kalawewa, Meegalewa, and Kalankuttiya tanks, to keep track of the actual volumes transferred daily and observe possible deviations from the targets.

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[1] The canals studied are: Kalankuttiya Branch Canal, Santo Domingo Area Main Canal, Kirindi Oya Right Bank Main Canal, and Rajangana Pilot Distributary Canal. Improvements at the level of the canal studied often depends on interventions at higher levels in the main system which have not been investigated with the same amount of detail in the study. They are mentioned however in the list of potential areas for improvement.

3. Regulation of the Kalankuttiya Branch canal - The division of responsibilities for the operations of the branch canal between two blocks, Galnewa and Meegalewa, as at present would not facilitate the regulation of the canal, should this be attempted by the agency. A channel of communication would have to be established to permit regular communication of information regarding the status of flow at the tail (307-D3), as well as the rainfall, to the Irrigation Engineer responsible for the headworks. Unlike other systems, the regulation of the branch canal can be achieved with feedback focusing essentially at the tail of the canal. Installation of a stage recorder at the tail as originally planned in the design would prove useful to that end to reveal anomalies in the diversion of water at the distributary channels from the branch canal. Other suggested improvements include: (i) repair of the headgate and sealing of a leak which represented 13 percent of the total water issues for yala (dry season) in 1988: (ii) upgrade the calibration at the hump gage of offtakes where the weir boxes are physically and hydraulically fit, and calibrate gate orifices as an alternative wherever weirs are destroyed or submerged; (iii) supervise more closely the eight offtakes[2] which do not benefit from the regulating effect of duckbill weirs: (iv) deliver simultaneous water issues to all distributary canals along the branch canal instead of shifting supply between the upper and the lower portions as was done in the past.

Kirindi Oya Right Bank Main Canal (RBMC)

4. Improve upward communication to the Water Management Feedback Center regarding progress of cultivation in the command area and rainfall - In order to optimize water allocations from Lunugamwehera Reservoir, and to determine water issues at the head of the system, as well as at the various offtakes. along the RBMC during the season, monitoring and feedback procedures from the Resident Engineer Right Bank's (RE-RB) office to the Water Management Feedback Center need improvement. In particular, rainfall information at Weerawila would need to be considered as it may differ widely from the rain observed at Lunugamwehera. The capacity of the RE-RB office to monitor, on a weekly basis, the progress of the cultivation in each unit command area and to process this information in a timely manner, might need strengthening. Similarly, the Center could assist RE-RB in building and maintaining a database of the key parameters needed for the RBMC operations such as: the calibration of the weir or gate opening at the offtakes, better assessment by field measurement, of adequate supply discharge at the head of distributary canals from the main, given the actual disparities in soil conditions, etc.

5. Improve downward communication from the Headworks to the RE-RB - All interventions to be made at the RBMC headworks should be communicated with prior notice (a few hours preferably) to the RE-RB, with indications of the flow intended at the main sluice before and after, and the intended time of the intervention. This is necessary for RE-RB to instruct each gatekeeper in charge of the cross-regulators and offtakes of the timely maneuvers which they should perform (re: Recommendation 7 below).

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[2] These include the 3 offtakes at the head, the 3 offtakes at the tail, plus 305-D4 and 309-D1 in the middle portion of the branch canal.

6. Suppress the variability of flow associated with the maintenance of the syphon - The design of the grill which protects the entrance of the syphon is inadequate and gets clogged daily by weeds. This has been a frequent source of disturbance for the downstream portion of the canal, provoking occasional overtopping of the bank. This grill should be removed, and other means to ensure people's safety should be used, such as a floating cable anchored across the canal some distance upstream of the syphon entrance, fencing, ladder, etc..

7. Improve the manageability, of the RBMC: Develop a set of specific procedures for more effective operations of the main canal - Because the hydraulics of the RBMC are excessively complex, operational options should be investigated by simulation through a mathematical model[3] of the canal.

(a) A first option includes the development of a set of timely operational procedures with the objective of stabilizing more quickly than at present the regime of flow in the main canal after any substantial change of target delivery at the head or at an offtake, while keeping water at Full Supply Depth in the various reaches. Results anticipated will be a minimum of interventions at the cross-regulators. Intervention would be timely and guided by the prior knowledge of the final setting of the gates corresponding to a given pattern of steady distribution of water, hence improving on the current trial and error mode of operations at the regulators. Current canal operation practices which emphasize the maneuver of cross-regulators are expected to shift, with more attention paid to the control of flow at the offtake (re: Recommendation 8 below).

(b) Other possible options to be investigated in view of the regulation of the canal are associated with (i) upgrading the communication facilities to permit feedback regarding the hydraulic status of the canal in real-time (or alike) and improvement of direct communication with operators along the canal, or (ii) exploring the prospect of creating lateral storage on the side of the canal at some intermediate section (re: Recommendation 9 below).

8. Improve the control of water issues at the offtakes - The current weir-box-cum-baffles provided by the design to assess the flow diverted have proven inadequate. Many of them have already been destroyed, and the agency envisages replacing them by Broad-Crested Weirs (BCW) said to be less sensitive to submergence. Considering the limited head loss available between FSD in the main canal and the offtake canal bed, Parshall flumes might be advisable, and this option should be explored.

9. Explore prospects to improve the regulation of the canal -

(a) First direction: A major difficulty in regulating the canal in ways that would be responsive, is 'the absence of intermediate storage capacity that can be mobilized for the regulation of the canal. These present

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[3] Such a model to simulate steady and unsteady flow has already been developed by IIMI through a special project supported by the Government of France. The model is currently calibrated and operational.

difficulties are expected to be exacerbated with the operation of Phase II, now under construction, that will extend the length of the main canal to be regulated. It would be advisable to explore the prospect of creating at some point on the right side of the main canal some lateral storage capacity which can act as a buffer. The operation of the canal would have to be modified in accordance, to manage the filling of such an intermediate storage, but this is expected to improve substantially the potential manageability of the system in the newly extended portion of the tail of the RBMC. Investigations regarding the change in operations required to regulate the system with the inclusion of the lateral storage would best be undertaken by means of the available simulation model of the canal.

(b) Second direction: there is presently a great deal of "downstream" control of the system through the current practices of the Irrigation Laborers who tend to adjust water issues at the offtake in a way that can satisfy farmers' "demands." In the future, the need for more flexibility in the supply of water at the offtake is expected to increase as the project moves to more crop diversification as intended. Considering the difficulties anticipated in the upstream type of regulation of this system, given the particular design, it would be advisable to explore the prospects for employing a downstream type of regulation and to identify the changes that would be required: (i) in the rules of operating the canal; (ii) in the communication of information; and (iii) in the regulating structures and embankment of the canal. Particular attention should be paid to the effective control of the water issues at the offtake and their supervision to prevent abuses. This type of investigation would be best conducted through the available simulation model of the canal.

UPRIIS - Diversion Canal DC#1 - Santo Domingo Area (SDA) Main Canal

10. Improve the control of water issues at the head of SDA - Regulation of the supply at the head of the SDA Main Canal has been identified as a key area with potential to improve effectiveness in the management of the water within the Santo Domingo Area while optimizing use of the local flow. But this also depends to some extent on the level of improvement which would be possible to achieve in the regulation of the Diversion Canal DC#1 (re: Recommendation 11 below).

At the head of SDA, better achievement of target water issues and reduction of the variability of the inflow can be expected with the following: (i) Improve monitoring of the inflow to SDA at 5-Bay Checkgate. The upgraded calibration of the main Parshall flume performed by IIMI can be used, although the flume is occasionally submerged. An alternative would be to calibrate the orifice of the SDA headgates (never operated) and assess the flow from a measure of the differential head through these gates. The installation of a stage recorder at that location would also be advisable to monitor the adequacy of the supply to SDA; (ii) upgrade the communication of information between that location and the operator of the SDA supply headgate from DC#1. This operator should receive at least daily feedback regarding the actual inflow at the SDA headgate; (iii) develop the procedure to be followed by the operator of the SDA supply headgate and assign the following tasks: (a) estimate the daily local flow in the creek from the difference between the inflow monitored at the SDA headgate and flow diverted (existing measuring station maintained by the Hydrologist); and (b) adjust the diversion of water from DC#1 to supplement the local flow *so* as to meet the delivery target set for the Santo Domingo Area by the Hydrologist. Monitoring and evaluation of the compliance of the operator with this task could be achieved by the Hydrologist on the basis of records of the inflow at the head of the SDA Main Canal.

11. <u>Improve the regulation of the water conveyance through the Diversion Canal DC#1</u> - Improving the control of water issues taking off from the Diversion canal should be a priority. The present level of supervision along DC#1 does not seem adequate to achieve *any* sort of regulation of the canal. It minht be desirable to strengthen the operational capacity of the Water Control Coordinating Center (WCCC), with adequate staffing, including gatekeepers and supervisors, to be placed under the WCCC authority and payroll. Considering the far-reaching impact on the overall performance of the system of the regulation of a large canal like DC#1, it might be justified for NIA to concentrate efforts and means to regain what seems to be a loss of authority and to eradicate illegal interventions of the magnitude of those observed at Radial Gste RG#3, for instance. Further improvement of performance in water management appears highly dependent in respect of law and order at the level of DC#1.

The principle underlying the operation of the diversion canal is that DC#1 should supplement local flows eventually available at the head of the various irrigation subsystem. Although not investigated in the present study, the control of water issues at the head of each subsystem should be expected to follow operation principles similar to those quoted above (re: Recommendation 10). If this were to be applied, the diversion canal DC#1 should preferably be regulated in a downstream mode which means that the operation rules at each Radial Gate along DC#1 should be to fill the downstream reach. The prospect of implementing such a mode of regulation should be investigated, preferably on the basis of hydraulic simulations of the flow in the canal.

If feasible, this option would greatly improve the responsiveness of the system and facilitate the management of the conveyance and the communication of information associated with it. However, there are <u>two conditions</u> for its feasibility: (i) effective control of water issues from DC#1 and associated "policing" along the canal (as mentioned above); and (ii) flexibility in the quantity of water released from Pantabangan Dam, to be adjusted taking into account the variation of the water "demand" of DC#1 and monitored at the head of it.

12. <u>Improve the distribution of water within the Santo Domingo Area</u> - So far. the regulation of the supply at the head of the SDA subsystem is poor. Some limited- improvement could be achieved by fine-tuning the quantity of water diverted from DC#1, but it does not seem realistic to envisage any regulation of the water transfer along the SDA Main Canal. This is because of the current design of the canal which provides an excessive number of opportunities for ad-hoc checking, ruling out possibilities for coordinated operations along the canal. Therefore, the system seems bound to be operated

under a rather large variability of flow, increasing from the head to the tail of the main canal.

Under these circumstance!; the actual mode of distribution adopted by NIA's staff at the lateral, i.e., sharing the water in proportion to the area under command of the major canals, seems appropriate and might remain, though the large variability of flow is expected to have a negative impact on the erosion of the canal banks and structures.

However, the design of the structure at a branching point does not fit the present water distribution principles (although gatekeepers, with experience, succeed to manage the division of water through the operation of the undershot, gated cross-regulators). Given the fact that most of these structures are currently in a critical state of disrepair, it seems appropriate to envisage their replacement by proportional flow dividers in the course of a rehabilitation program. A refinement of the design would be to provide dividers which can be adjusted. This would permit fine-tuning of the division in accordance with the cultivated area in both branches with consideration for the expected conveyance losses, etc., and would allow adjustment of the proportion to eventual changes occurring from season to season in the extent of the area cultivated under a branch.

Rajangana Pilot Project

13. Restore openness regarding the distribution of flow within the Pilot Area - The hydraulic level control at the tail of the Pilot canal should be restored as it is essential for the equitable distribution of flow amongst field canals along the DC. This should be done simply by restoring the width of the last duckbill weir, whose function is to provide hydraulic control of the water level as required for the correct functioning of the three baffle distributors located at the tail of the pilot DC. This weir therefore'is not a good measuring device. However, some kind of flow monitoring at the tail is essential, as this should be the main indicator to be used by the Irrigation Laborer for canal supervision.

Therefore, such monitoring should not be viewed by the operator as being only for the purpose of filing a record, but as a means to oversee easily the regulation over the canal and to detect any unexpected alteration of the distribution.

Openness regarding the distribution of flow within the Pilot area was the main thrust of the experiment toward improved manageability. This should be restored if any lesson is to be learned by the Agency from this experiment.

14. Reconsider the objective of a rotational mode of delivery in Pilot area - A major source of the difficulties faced in the operation of the Pilot canal related to the initial objective set by the Irrigation Department regarding the introduction of a rotational mode of delivery in a water surplus environment. This was not conducive to the adoption of such a practice which has been rejected by the farmers. Drawing lessons from this, it would be advisable to revise the unrealistic objective set for the pilot

project as it was for the rest of the scheme. This would lead to replacement of the 9-inch pipe farm outlet provided in the Pilot area by the previous 3-inch pipe which farmers favor for the continuous water issues which they are going to implement anyway.

15. <u>Manage the transfer of technology</u> - A number of shortcomings were identified in most phases of the Pilot Project implementation: planning and design, construction, operation, maintenance of the technology, including the process of monitoring and evaluation of an experiment intended to generate training. Most of these difficulties are in the realm of the management of the Transfer of Technology, but. this stretches beyond the scope of the present study.

CHAPTER I

INTRODUCTION

Main System Management (MSM) has been pointed out as a "blind spot" to be investigated which holds the key to better performance of irrigation systems. Its potential has been confirmed by research and experience. Main system management has however not been a subject that has received much professional attention. Professional gaps have been identified in the training of irrigation engineers, in engineers' ideas, as well as in social scientists' preoccupation with local-level social and organizational issues (Chambers, 1988).

These gaps are reflected in the literature by the relatively little information readily available regarding the manageability of main systems and the performance achieved at that level, when compared to the number of studies of the water distribution at the farm outlet and canal turnout.

This present comparative study is an attempt to fill this void by documenting with a management-oriented approach the reality of main canal operations with particular reference to the implications of the planning and design aspects for the manageability of the systems, for their performance, as well as for the organization of the irrigation agencies.

The analysis has been conducted at three irrigations systems in Sri Lanka and one in the Philippines, displaying original features in the design of their main canals. The methodology adopted refers to a dual approach in the realm of: a) Performance Control for Professional Management, and b) Control of Deliveries and Canal Regulation.

Much of the information mobilized for the study was collected in 1988 during one irrigation season only. This was done through (a) intensive automatic recording of canal water levels using modern data-logger technology procured under a grant by the Government of France to IIMI, mainly for the purpose of the study, and (b) careful field monitoring of water flow and canal operations. The study also drew upon previous work conducted by IIMI on the same systems as well as results generated by simulations performed through available mathematical models of the canals.

1.1 TERMS OF REFERENCE

The subject of the study refers to the interactions between the design and the management of main systems and their impact on performance.

The terms of reference for this activity relate broadly to the notion of regulation of main canals, its impact on the distribution of flows from the main canal, its contribution to the manageability and ability to operate the physical systems and the implications in terms of managerial requirements for the irrigation agencies.

Further elaboration on the concepts of Canal Regulation and Manageability is given below to better define the focus and scope of the study.

1.2 DEFINITIONS

Main system management refers to the management or software aspects of the capture, allocation, scheduling, and delivery of water on main systems down to, and including, outlets, and the disposal of water in drains. It includes planning, decision making, the operation of controls, and communication both upwards to managers and downward to groups of farmers (Chambers, 1988).

Regulation is the process or act of manipulating and distributing water supplies available at the source of supply as per the demands of the users, between different offtaking canals or amongst branches, laterals, and distributaries on the same canal, the main purpose being equitable distribution of water, control of harmful silt entry into canals, delivering of required discharge at every point in the network and facilities for their measurement, and in the case of untoward incident or false operation, limiting of water losses and avoiding of any damage (ICID, 1967).

1.3 CONCEPTS AND APPROACH

Canal Regulation - The concept of canal regulation encompasses both the formulation and the execution of an operating plan for the use of water in a canal system. It includes the operation of storage and diversion works to adjust water levels in canals and in reservoirs and changes in streamflow. This process which comprises the definition of objectives, setting targets, operations of structures and feed-back regarding the attainment of targets with a view to further operations, adjustments and/or changes in targets is referred to as a control process. This notion of a control process is one of the concepts utilized in the analysis.

Functions of Main Canal - The essential role of a main canal is to convey the water from a source of supply to often remote places of primary delivery. This encompasses two functions: the transport of water along the canal and the issue of water at some locations. Depending on the order and dimensions of the canal, one or the other function might predominate and the canal might be viewed either as a conveyance system or as a distribution system. Yet, main canals are often called upon to perform both functions simultaneously. In such cases the adequate regulation of the water conveyance becomes a condition for the control of water issues.

Investigating whether and how these aspects have been taken into consideration (a) in laying out and designing main systems and main canals, and (b) in the organizational setup of the irrigation agencies in charge of operating these canals provide the framework of the study.

Manageability - The notion of manageability has been tentatively elaborated from two different perspectives in the **study:**

a) the *manageability* of the system in terms of' the difficulties and constraints faced by the irrigation agencies in handling the managerial process - the flow of information associated with decision malting - which takes place at the various levels of responsibility within an agency, given the structure and procedures of the organization, the capacities and motivations of its staff, the facilities available to them to communicate information, etc. This process is required for the canal regulation throughout, extensive main systems; and

b) the manageability of the system in terms of the difficulties and constraints faced by the operator in the control of the physical process- the flow of water - given the physical conditions of the control structures, storage capacities if any, the information available to him in respect of both delivery targets and actual water issues, and in particular, volume delivered.

Thus, one approach adopted for the study has been to analyze how the agencies have organized themselves for the management of main systems. The various **administrative-managerial** levels involved were identified, starting with the level where the concept of regulation of the canal system as a whole is being formulated, to the level of the operators. This included the **analysis** of the decision making taking place at each level including the participation of others in the decision preparation phase, the information available, the messages communicated to the next level of decision, and the monitoring of the effects.

Another approach which **was** followed consisted of assessing whether the conditions for effective control of water deliveries and for the regulation of the conveyance of water were available at the appropriate levels in the canals studied. These conditions include a recognition of whether operational targets are explicitly formulated and known by the operators,, whether they have the possibility to obtain reliable information on water flows (and volumes), and whether they have the means to intervene on the water issues or the water stored, or both. Particular attention has been devoted to analyze the role that the layout of main systems and the design of main canals can play in the creation of more or less favorable conditions for the control of the delivery and conveyance functions.

Operators are normally not expected to make decisions but to comply with standing orders, execute instructions received, and report. But field observations indicated that the room for decision making at the level of gate-keepers, irrigation laborers, etc., is often greater than expected and this has implications for the overall management of the system.

The analysis of the operational flexibility provided **by** the design and its implications on the room left to the operators for decision making measured against the information available to them regarding the complexity of the particular process which they have to deal with is central to the study.

Finally the question to be addressed is: what kind of flexibility is still manageable?

1.4 STUDY FOCUS AND SCOPE

Focus - As indicated above, the focus of the study has been defined to address the following issues:

The impact of planning and design characteristics of the systems on:

* the Administrative-Managerial setup of the Irrigation Agencies;

* the Manageability of the systems: i) Control of the delivery function and ii) Regulation of the conveyance function;

* the Performance of main canals: i) Control of water level at specific locations; ii) Control of water flow delivered at distribution points along the main canal.

Scope - The study compares the following issues across the four systems studied:

* Identifying the features of main systems layout and main canal design which are significant from the point of view of the regulation of the water conveyance and the control of deliveries;

* Identifying the levels of decision making regarding canal operations, the tasks of the staff, and the communication of information taking place in that process;

* Investigating the availability and clarity of the objectives regarding the distribution of water, and the availability of operational targets for the control of water issues at the head of the subsystem studied as well as from the main canals;

* Assessing the availability of information regarding water flows along main canals and at the offtakes; identifying the constraints and exploring possible ways to improve the reliability and the effectiveness of the monitoring of water flows;

* Assessing the availability of means for influencing the flows at the offtakes; identifying the operational constraints given the physical structures available; examining the room for decision making left to the operators given the flexibility of the system;

* Examining whether the notion of dynamic transfer of water volumes along main canals is perceived as an explicit objective;

* Assessing the possibility of mobilizing intermediate storage in tanks and/or canals as buffer capacities;

* Assessing the appropriateness of the existing means of communication and the provision of feedback to the decision-making level that oversees the canal; and

* Evaluating the levels of performance achieved through main canal operations in terms of water level control and equity of the primary distribution of flow along the main canal.

Besides the above, there are other important issues relevant to Canal Regulation, which are beyond the scope of the present study; in particular, the management processes taking place at the system level in regard to the reservoir management and the water allocations. This includes procedures to (a) assess and forecast the water resource availability using hydrological information, and (b) monitor the progress of irrigation cultivation, assess water requirements, and aggregate the demand up to the system level.

These are all important management processes from the point of view of canal regulation because the decisions made through these processes influence the formulation of the operational plan and the definition of the targets required for the conveyance and distribution of water within the main system.

With respect to the present study, the availability of targets as set by the agencies will be considerel as one of the conditions required for the control of the distribution and as a reference for the evaluation of performance. But the validity of these targets, the ways in which they are defined and eventually updated will not, be questioned under the present study.

1.5 METHODOLOGIES

Four irrigation projects were selected for the study by IIMI - three in Sri Lanka and one in the Philippines. The choice was carefully made so that, on the whole, a diverse set of canal regulation technologies was represented. The list of the canals studied and their position .vis-a-vis the projects and the larger systems is indicated in Table I-1.

The salient features of the layout of these systems and of the design of the main canals studied are presented in Chapter II of this report.

Special mention has to be made regarding the Rajangana Pilot Area. This refers to a small area of about hundred hectares under the command of a distributary canal located on the left bank main canal of the Rajangana irrigation scheme. This canal was considered as an alternative to a similar Pilot Area of comparable size existing at the Huruluwewa irrigation scheme, which was originally intended to be the fourth subsystem in the present comparative study. This idea had to be abandoned because a serious water shortage prevented any cultivation being undertaken in the Huruluwewa irrigation scheme during the period of the study. Both Pilot Areas are part of the Major Irrigation Rehabilitation Project (MIRP) undertaken by the

Irrigation Department with the support of the World Bank. One of the PIIRP Pilot Areas was considered of interest for the comparative study because of the special design principles and control technologies adopted for the water distribution in distributary and field canals.

Table I.1. List of canals studied with reference to the projects and systems.

PROJECTS	AGENCIES	MAIN RESERVOIR	SUBSYSTEM	CANAL STUDIED
Upper Pampanga River Integrated Irrigation System (UPRIIS)	National Irrigation Administration (NIA), Philippines.,	Pantabangan multipurpose reservoir	Santo Domingo Area (SDA), (District I, Zone 3)	SDA Main Canal (SDA-MC)
Galnewa Project in Mahaweli System H	Mahaweli Economic Agency (MEA), Sri Lanka.	Kalawewa Tank (supplemented by diversions from Mahaweli River)	Galnewa-Meegalewa Block	Kalankuttiya Branch Canal (BC)
Kirindi Oya Irrigation 6 Settlement Project (KOISP)	Irrigation Department, Sri Lanka.	Lunugamwehera Reservoir	Kirindi Oya Right Bank	Kirindi Oya Right Bank Main Canal (RBMC)
Rajangana Irrigation Scheme	Irrigation Department, Sri Lanka	Rajangana Reservoir	Rajangana Pilot Area	Distributary Canal DC1 in tract 2.

The same analytical approach to assess the impact of the planning and design characteristics on the manageability of the system (Chapter IV) was applied to each of the four canals studied irrespective of their size.

As mentioned in the <u>Inception Report, February 1988</u>, the bulk of the research effort has been concentrated on trio primary systems which exhibit. very different concepts for canal regulation: Santo Domingo Main Canal in UPRIIS (Philippines), and Kalankuttiya Branch Canal in Mahaweli System H (Sri Lanka). Although not envisaged initially, a case study to address the organizational aspects of the regulation of the Kirindi Oya Right Bank Main Can31 (RBMC) was also performed. This case study was carried out. with the support of the Dutch Government and the results made available for use in the present comparative study.

Intensive field monitoring has been performed throughout the irrigation season at the two primary systems considered for the study. At the trio other systems, the field monitoring has been concentrated at specific locations: at the head of the pilot distributary canal at Rajangana (and also at a control distributary canal used by the Irrigation Department as a reference); and at two cross-regulators and diversions along the Kirindi Oya Right Bank Main Canal. This made it possible to enlarge the range of the regulation technologies being studied.

IIMI staff performed field monitoring of water floras and gate operations in the course of one irrigation season in 1988 as follows:

- Santo Domingo Area: July to October 1988 (Wet irrigation season)
- Kalankuttiya BC: May to September 1988 (**yala**, or dry season)
- Kirindi Oya RBMC: March to July 1988 (maha, wet, t intermediate season)
- Rajangana Pilot Area: in August 1988 (**yala** season).

This monitoring effort **was** considerably strengthened by the installation of 12 automatic recording stations over the four sites, using electronic data-loggers, as well as classical stage-recorders. Altogether a total of 31 different sensing pints were dispersed at key locations along the main canals studied and at particular branching points. Table 1.2 shows the location of the various recording stations installed for the purpose of the study in each canal. These data, together with information obtained from other sources and from interviews of the operations staff, have generated a substantial body of information regarding the actual operational practices of the control structures and have made it possible to document faithfully the flow conditions prevailing in these main canals.

However, the analysis of the data collected on the two primary sites was constrained by the limited time which became available for this process as a result of the late termination of the irrigation season when compared to the schedule imposed by the time frame of the study.

CHAPTER II

PLANNING AND DESIGN CHARACTERISTICS OF THE IRRIGATION SYSTEMS

The four systems considered in the study are actually part of larger reservoir-based irrigation projects originating at dams which are good examples of Filipino and Sri Lankan engineering expertise. References to these projects, their managing agencies, and the definition of the subsystem considered for the study have already been made in Table 1.1 on page 6.

Special mention has to be made regarding the Rajangana Pilot Area which is by far the smallest in size of the four subsystems studied. The Pilot Area refers to the 94 hectares (ha) under the command of a distributary canal (DC1) located in tract 2 of the left bank main canal of the Rajangana Irrigation Scheme. This site was included in this comparative study because of the particular features displayed by the design of this canal. Despite the enormous difference in size of this canal compared with the other three, it has been possible to apply the same analytical approach to all four systems considered in this study.

2.1 PROJECT DIMENSIONS AND LOCATION OF THE CANALS STUDIED WITHIN THE WHOLE SYSTEM

There are disparities in the sizes of the larger projects to which the subsystems studied belong. It is important to consider these aspects as well as the location of the canals studied with respect to the main system of which they are a part.

In terms of size of the command areas under (i) SDA Main Canal, (ii) Kalawewa Left Bank Main Canal, (iii) Kirindi Oya Right Bank Main Canal and (iv) Rajangana Left Bank Main Canal, the four range between 4,000-10,000 ha, but the most significant differences are in terms of:

* the design features of the conveyance system and its extent up to the head of the subsystem studied. In particular, the distance to the head of the subsystem studied from the principal source of water - a storage reservoir in general - and the availability of intermediate storage in between are essential aspects for the regulation of the transport of water from the source to the delivery point of particular interest - the head of the subsystem studied.

* the density and the type of the facilities provided by the design for the regulation of flow within the subsystem - including intermediate tank storage - and for the diversion of water off the main canal.

Figure 11.1 is a comparative presentation of the schematic layouts of the main systems considered, highlighting the locations of the canals studied within the whole system.

2.2 THE UPPER CONVEYANCE SYSTEMS AT THE HEAD OF THE SUBSYSTEM STUDIED

The upper portion of the larger system can be considered as a conveyance system with respect to the location of the head of the subsystem studied. Some key parameters describing those systems are summarized in Table II.1.

The Kirindi Oya Right Bank Main Canal. takes off directly from the Lunugamvehera Reservoir and therefore the mobilization of the water resource into the canal studied does not depend upon any conveyance system at a higher level. Figures 11.2 and 11.3 indicate the site location and the issue tree diagram of the right bank main canal.

The Rajangana Pilot Area covers the command area under distributary canal No.1 (DC1) taking off the left bank main canal (LBMC) in its upper reach (tract 2). Thus the conveyance system from the dam to the head of the Pilot canal is only 5 km long and this is of limited practical consequences for the transport of water. The Rajangana Tank is a main storage reservoir for the area under command but it has to be pointed out that it also receives substantial drainage water from the Mahaweli System H, the Galnewa and Meegalewa regions in particular, located between the left and the right bank canals of the Kalawewa Tank (see Figure 11.4).

The Kalankuttiya Branch Canal is actually the tail section of a lateral branch of a main canal that originates from the left bank of the Kalawewa Tank in Mahaweli System H (see Figures 11.4 and 11.5). System H is itself a component of the vast Mahaweli Ganga development project for hydropower and irrigation. The Kalawewa Tank's own resources are augmented by Mahaweli Ganga water through transbasin diversions at Polgolla and Bowatenna. A cascade of intermediate tanks - Galnewa, Mulannatuwa, and Kalankuttiya - spread along a 25 km long main canal is the salient feature of the conveyance system.

The Santo Domingo Area (District I, Zone 3) is located more than 50 km away from the Pantabangan Reservoir - the only storage of the Upper Pampanga River Integrated Irrigation System (UPRIIS). Figures 11.6 and 11.7 indicate the locations of the Santo Domingo Area (SDA) in relation to the UPRIIS service area. Pantabangan is a major reservoir constructed to generate hydropower and to supplement a series of run-of-the-river irrigation systems existing prior to its construction. As such, the supply of the Santo Domingo Area is from the Sapang Kawayan Creek, a natural water course which receives the drainage water from the Talavera River Irrigation Systems (TRIS: District I, Zone 2 and UTRIS: District I, Zone 1). Figure 11.8 is a schematic representation of the irrigation network of the SDA.

From Rizal Dam on the Pampanga River, a 23 km transbasin canal (DC#1) of 45 m^3/s maximum capacity, conveys the water released from the Pantabangan Reservoir and delivers it through 5 major diversions along the way to the following areas: Pampanga River Area, Rizal Munic Area, Vaca Area, Lower Talavera Area, and finally Santo Domingo Area. These areas belong to the two separate administrative districts: District I and District II. DC#1 first serves District II before entering District I. The Santo Domingo Supply Headgate itself takes off from the transbasin canal DC#1 near its tail.

Thus, the salient feature of this conveyance system that ends at the head of the Santo Domingo Area is a cascade of 4 major diversions: Rizal Dam, DC#1 Headgate, SDA Supply Headgate taking off DC#1, and finally 5-Bay Checkgate where the head of the SDA Main Canal is located.

2.3 IMPACT OF THE LAYOUT OF THE CONVEYANCE SYSTEM ON THE AVAILABILITY OF WATER AT THE HEAD OF THE SUBSYSTEMS STUDIED

At Kirindi Oya, the water is immediately available at the head of the subsystem studied as long as the resource is available in the Lunugamwehera Reservoir. The volume of water stored in the reservoir at the start of the irrigation season studied (maha, wet season, 1988) was adequate but the area had experienced severe water shortages during the two previous seasons.

The Rajangana irrigation scheme, as a result of its geographical location in relation to Mahaweli System H, is reputedly a water surplus area. There was no constraint of any sort with respect to the availability of water resources in the pilot area. Towards the end of the season studied (yala, dry season, 1988) it was even observed that the Agency had difficulty to empty the reservoir for carrying out some repairs at the headgate even though the water issues into the left bank main canal were maintained at a very high level for a long period of time. On the other hand it was observed that the Rajangana left bank main canal, being a single bank canal, received appreciable quantities of water as runoff during rainfall, even in the upper reaches. This, coupled with temporary closures of the main canal, are sources of variation in the water depth in the main canal at the head of the pilot canal. The design of the pilot project, with the provision of an automatic hydro-mechanical gate (AVIO type) at its head, aims at alleviating this difficulty. Hydraulic conditions that are appropriate for the control of flow into the distributary canal are restored, irrespective of the level variations in the main canal. This point is further discussed in Section 4.2 of the present study.

The layout of the Mahaweli conveyance system that includes a number of large and intermediate storage tanks, together with the current management practices of the agency with respect to this conveyance system apparently makes it possible to ensure the availability of adequate water resources at Kalawewa and at Kalankuttiya, at least when the hydrology is normal. There was however a notable exception recently, during maha 1986-87. The failure of the monsoon rain did not permit adequate natural filling of the Kalawewa Tank, which resulted in a higher water demand placed on the transbasin diversions and on the overall management of the conveyance system. In the case of the season during which this study was undertaken (yala 1988), it appears that the resource available at Kalawewa and Kalankuttiya was relatively abundant.

The UPRIIS conveyance system is basically different from the Mahaweli conveyance system in that water is carried to supplement run-of-the-river systems instead of to supplement the stored resource of tank-based irrigation systems as in the Mahaweli. Unlike the Kalankuttiya Tank which permits an almost immediate response to requests for water from the command area, it may take up to two days for the "pure" water (from Pantabangan Reservoir) to reach the Santo Domingo Area with a non-negligible risk of "mishap" on the way, despite the efforts exerted by the staff and the means of communication available to them to coordinate operations in real-time.

Furthermore, the resource available in the Pantabangan Reservoir was exceptionally low in July 1988 at the start of the wet season during which the study was conducted. By mid-September, the situation became critical because of the failure of the August rains (93 mm against 400 mm expected according to past records). Thus, the reservoir did not refill and the level was at its lowest since 1983. This situation impinged dramatically on the water availability at the head of Santo Domingo Area. This is further discussed in Chapter IV of the present report.

Preliminary conclusions: 'The overall storage capacity provided for by the design of irrigation main systems in relation to (a) the hydrology, and (b) the extent of the program area, is an important parameter as it conditions to some extent the ability to mobilize the water resource in the course of the irrigation season, particularly at the beginning.

The provision of some intermediate storage facilities (e.g., tanks) close to the areas to be irrigated plays an important role in facilitating the management of the water transported in the main system towards the head of individual subsystems.

These situations are illustrated by the comparison of the Kalankuttiya Branch Canal with Lateral B in the Santo Domingo Area, both of which have command areas of similar size. Quantitative control of water issues is achieved reasonably well in the first case, while only proportional sharing is achieved in the second. (cf. Chapter IV in the present study.)

As a result of the planning and design process, systems are provided with a layout that could include facilities for the storage of water. Depending on this layout, the regulation of the conveyance system might require efforts that cannot be met by the current managerial capacity of the agency. The availability of some storage capacities close to a supply area of limited extent has been shown to simplify the regulation of a conveyance system aiming at ensuring adequate and timely water delivery at the head of these subsystems. In other words, the complexity and difficulty involved in managing a main system in an effective and responsive manner increases dramatically as the buffer capacity available between conveyance and distribution decreases. The more extensive the project, the more relevant are these aspects. In the absence of decentralized storage, regulation calls for more sophisticated techniques in the realm of automatic control and real-time communication of information.

Significant discrepancies exist in respect of the actual availability of (stored) water at the start of an irrigation season and the hydrological changes observed thereafter, from site to site and from season to season, even in the case of the larger reservoir-based systems studied. This indicates that in any event, given the facilities provided by the design for water conservation, there is a critical management domain to be dealt with at the system level involving water resource management, strategic planning and hydrological forecasting. However, it is not intended to elaborate on these aspects in the present study whose focus is more limited.

2.4 SALIENT DESIGN FEATURES OF THE MAIN CANALS STUDIED

A wide range of, parameters can be used to characterize the design of irrigation canals, but there are some that have particular significance for (a) the hydraulics of the canals, and (b) the constraints generated for the effective operation of the control structures under the different flow conditions that prevail in the canal. The physical characteristics of the canals studied are indicated in Table 11.2.

Longitudinal gradient, density of cross-structures, and location of offtakes. Besides the physical characteristics listed in Table 11.2, other important parameters are: (a) Longitudinal gradient, (b) density of cross-structures, and (c) location of the offtakes.

The topography of the command area and the gradient available for tracing main canals determine, to a large extent, the possibilities to erect regulators, weirs, or drop structures along the canal.

There are significant differences amongst the canals studied, with respect to the average slope of the canal, and type and density of cross-regulating structures.

Table 11.3. Lengths and slope!; of the main canals and density of structures across the canals.

Canal	Length (km)	Average slope (m/km)	Cross-structures (unit)	Density per km (no./km)
Kalankuttiya BC	10.9	1.4	12	1.10
SDA Main Canal	24.4	0.9	46	1.88
Kirindi Oya RBMC	24.5	0.3	14	0.57
Rajangana Pilot DC	1.3	n.a	3	2.3

The contrasting longitudinal gradients of the Kalankuttiya Branch Canal, the Kirindi Oya Right Bank Main Canal and the SDA Main Canal are clearly visible in Figure II.9. Kalankuttiya Branch Canal has the steepest slope while Kirindi Oya RBMC has the mildest. The impact of these slopes on the design features of the canals is discussed below.

Figures 11.10, 11.11 and II.12 indicate the locations of the offtakes and the regulating structures on the main/branch canals with respect to the longitudinal profiles of each of these canals.

Table 11.4. Potential flexibility for "checking" provided by the design.

Canal	Number of cross-structures	Number of bays	Density (bays/km)
Kalankuttiya BC	12	2	0.2
SDA Main Canal	46	89	3.6
Kirindi Oya RBMC	14	61	2.5
Rajangana Pilot DC	3	0	0.0

The Santo Domingo Area (SDA) Main Canal has similar cross-regulator arrangements at each of the 11 major diversions to Laterals. The regulators do not have side-walls but the gates can be overtopped. Maintaining full supply depth in the canal no longer seems to be the rule for operating the canal. Instead, the current practice is to shut the gates of the regulator (or "check") to issue water to the lateral and to reopen the regulator gates when no diversion is required to the lateral. Controlling the flow at the lateral through the operation of cross-regulators tends to be the general practice and in some places it is actually the only feasible option since the gates of the lateral are missing (e.g., Lateral A). The SDA Main Canal has been constructed some 15 years ago and there are now only 6 gates actually operated at the cross-regulators out of 23 provided initially by the design. Even the gates that are operated are in a very critical stage of disrepair.

In addition to these, the design has provided a number of "checks" or "thresher crossings". These structures, evenly spaced every 500 meters, were apparently intended (a) to raise the water level at specific locations in the main canal, as required by the farmers, to facilitate diversion into the offtakes supplied directly from the main canal, and (b) to provide means for crossing the main canal. These structures consist of several bays, but no gates. They provide opportunities for ad-hoc checking by means of flash-boards, banana trunks, etc.. Observations indicate that farmers and agency staff place or remove checks more or less frequently although these operations are particularly inconvenient, cumbersome, and possibly dangerous.

Altogether, the cross-regulators and checks provide considerable flexibility and opportunities for intervention on the SDA Main Canal.

Preliminary conclusion: Amongst the canals studied, there are extreme situations with respect to the degree of flexibility provided by the design to adjust the water level. But the absence of this particular type of flexibility at Kalankuttiya and the Rajangana Pilot Canal appears to be more an advantage than a disadvantage from the point of view of the manageability of the system. (This point is further discussed in Chapter IV of the present study.)

than 2,000 meters upstream of the nearest downstream regulator. The degree of level control achieved by the manual operation of the gated cross-regulators has been studied at two locations GR3, at the head, and GR12, at the tail, of the main canal. (See Figures **IV.34** and **IV.35** for a schematic Layout of these measurement locations.) This aspect of level control will be discussed in greater detail in Chapter **IV** of this report.

The distance of **some** of the offtakes from the next regulator downstream results in a relatively large variation of the water level above the sill of these offtakes. The results of a computation of surface water profiles under different steady flow regimes along one reach of the main canal is provided as an illustration of the importance of the level variations affecting the flow diverted at the farthest offtakes (see Figure **IV.41**).

Neither the topography of the Rajangana left bank main canal nor of the pilot distributary canal was available for the study. The main canal, which is a single bank canal, appears to have a low density of cross-structures. Considering the pilot distributary canal, the design is based on similar principles to the Kalankuttiya Branch Canal although the dimensions of canals and command areas are smaller, Three small duckbill weirs have been constructed across the distributary canal to provide adequate level control as needed for the baffle distributors which equip the head of **each** field canal that takes off this distributary canal.

<u>Flexibility provided for "checking" across main canals</u>. ***As*** mentioned above, the design of the Kalankuttiya Branch Canal does not provide much flexibility for manual adjustment of the water level along the branch canal. There is actually only one gated cross-regulator (2 bays) built near the head of the canal and this gate is intended to permit water issues to the first two distributary canals, **305D1** and **308D1**, when the rest of the canal is shut off.

This design configuration is comparable to that of the pilot distributary canal DC1 at Rajangana, where there is not a single gate along the distributary apart from the shutters of the main baffle distributor at the head of the distributary canal.

As indicated in Table **II.4**, there is **a** marked contrast when compared to the high density of "checks" and gates provided in the original design of the SDA Main canal as well as Kirindi Oya **RBMC**.

At Kirindi Oya, the regulators consist of a combination of multiple gates of the undershot type (1-8 depending on the discharge capacity of the canal at the regulator location) with short side-walls whose crests are set at the design full supply depth **(FSD)**. These side-walls, **as** well **as** some of the gates, are usually overtopped when the regulator is fully closed. The Kirindi Oya Right Bank Main Canal is a newly constructed canal and most of the 61 gates of the regulators are still in working condition, many of them operated. Although the cross-regulators are operated in such a **way** that water overtops the side-walle, these weirs **are** too narrow to provide effective hydraulic level control.

At Kalankuttiya the available gradient, uneven in certain portions of the branch canal, was exploited to build a series of nine "duckbill weirs," two additional drop structures and one gated cross-regulator located about 150 meters below the head of the canal. These weirs, whose crests range from 4-25 meters in length, are designed to provide some degree of control over the water level upstream of the weir. This hydraulic property is further exploited by locating offtakes near the weir so that the flow diverted into the secondary canal is primarily dependent on the offtake opening irrespective of flow variations: in the parent canal.

Thirteen of the 20 distributary canals on the branch canal are located either next to the duckbill weirs or within a distance less than 200 meters upstream (see Figure 11.13). Previous studies (Berthery, Sally, and Arumugam, 1989) have indicated that the degree of level control permitted in the proximity of the duckbill weirs is of the order of 6-12 percent, expressed in terms of the ratio between the range of water level variation observed and the mean depth of water above the sill of the offtakes. This relative variation is about four times greater at the offtakes located at some distance from the weirs and benefiting less from the level control. The essential feature of the design of the Kalankuttiya Branch Canal is that it takes advantage of these aspects of level control in the primary canal to ensure control of flow into a majority of its distributary canals.

Figure 11.14 shows the maximum range of water level variation (obtained through a flow simulation model of the Kalankuttiya Branch Canal used in the study mentioned above) that could be expected above the different offtake invert levels when the flow released at the head of the branch canal varies from 0.5-6 m^3/s. This figure clearly demonstrates that maximum water level control is obtained in the immediate vicinity upstream of a duckbill weir and that the regulating effect soon disappears with distance.

Figure 11.15 (also taken from the above study) compares the simulated and observed relative range of water level variation at the distributary canal offtakes (field observations existed only in respect of 9 distributary canals). Similar conclusions regarding the comparative assessment of the design-related conditions affecting the water delivery at the offtakes, in terms of level control in the parent canal, can be reached, either through direct field observations or by model simulations.

The SDA main canal, on the other hand, exhibits a very high density of structures across the main canal apparently built to provide maximum flexibility. It includes 11 gated cross-regulators at the head of each major lateral canal and some 35 "checks", also called "thresher crossings". The checks are evenly spaced, about every 500 meters, throughout the length of the main canal to benefit the offtakes which are also spread evenly.

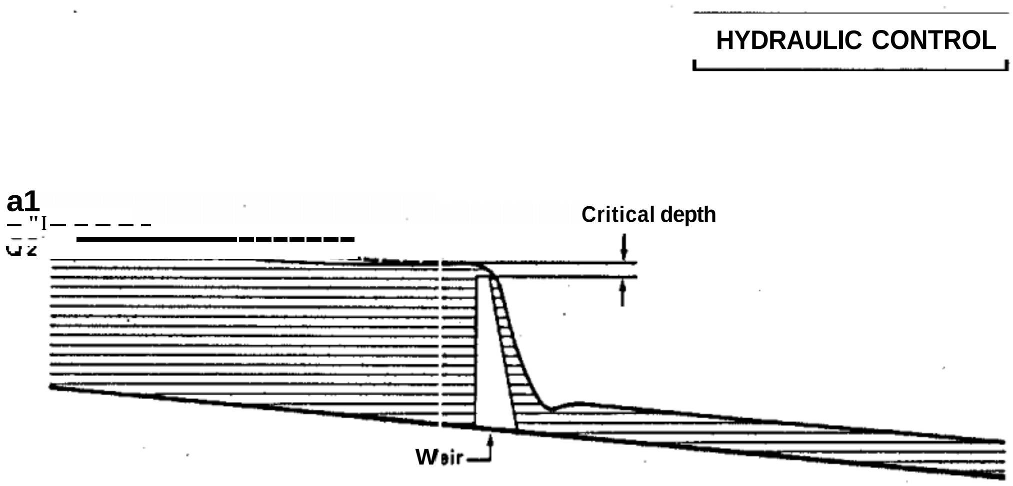
At Kirindi Oya, the gentle slope of the area was obviously a major constraint in the design of the right bank main canal which nevertheless provides 14 gated cross-regulators, fairly evenly spaced along its 24.5 km length. At least one distritutary or branch canal is located immediately upstream of the cross-regulators. The other secondary canals are spread over the entire length of the main canal, sometimes located at a distance of more

As a research hypothesis and a direction for further studies, it would appear that some of the flexibility of the "regulators" and the redundancy of some of the adjustable structures provided by the design is meant, to some extent, to cater to some foreseeable degradation of these structures and to provide back-up. Construction costs of gated regulators might be expected to be less expensive than solid weirs even if some of the gates are redundant.

Studying the economics of various types of regulating structures including the associated operation and maintenance costs weighed against the degree of performance achieved in terms of level control might be a promising avenue of research.

Availability of "controls: - This terminology refers to the hydraulic notion of "controls"[1] and critical flow* (see Figure II.16). Both are of

Figure 11.16 Hydraulic "control" and critical depth.



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[1] "... (T)he cross section in a waterway which is the bottleneck for a given flow and which determines the energy head required to produce the flow. In the case of open channels, it is the point where the flow is at critical depth; hydraulic conditions above the point being wholly dependent upon the characteristic of the control section and entirely independent of hydraulic conditions below the point ..." (ICID).

Complete control exists where the elevation of the water surface above the control is entirely independent of the fluctuations of water level downstream of it (ICID).

[2] Critical flow: That velocity of flow at which the energy of flow is a minimum (ICID). In other words, the maximum discharge per unit width for a given specific energy.

Sub-critical flow is produced by downstream control, and super-critical flow by upstream control (Henderson, 1966).

paramount importance in open channel hydraulics. It is not our intention to present a detailed discussion of the scientific bases underlying these notions. However, it is necessary to highlight the practical consequences of the hydraulic peculiarities of the canals that have resulted from their respective designs.

Most irrigation canals are equipped with gated cross-regulators built across the canal in order to raise the water head above the command area. But it is important to note that gated regulators are not "controls" as per the above definition. Gated-regulators produce sub-critical flow upstream, hence a backwater effect which might extend, depending on the canal bed slope, up to the next regulator and possibly interfere with the hydraulic conditions governing the flow through its gate orifice. This situation has the potential for creating hydraulic interdependency between canal reaches. An example of this situation has been observed at Kirindi Oya.

There are two operational constraints resulting from this situation:

a) the operations of gated cross-regulators might have unexpected impact on the upper reaches of a canal as well as downstream:

b) the assessment of flow is not always a feasible option in canals equipped with gated cross-regulators and the location of measurement sections will require special attention.

Natural obstructions or man-made structures such as weirs or drop-structures built across canals or steep changes in the canal bed profile could create hydraulic conditions (critical and super-critical) which are of practical interest for the operations of canal systems.

Practicing engineers often use as a memory device the fact that in super-critical flow "the water doesn't know what's happening downstream" (Henderson, 1966) and this is what is important in "controls."

Design of irrigation canals may harness these hydraulic peculiarities in many ways to:

a) provide means for the assessment of the flow in canals;

b) provide opportunities for flow control at lateral canals through improved performance in terms of level control at some section in the main canal; and

c) provide opportunities for decoupling the different reaches of the main canal, in particular preventing the downstream reaches (and associated laterals) from influencing the upper reaches, thereby creating the hydraulic conditions that fit the upstream control type of regulation prevailing in the irrigation systems studied.

The following analysis aims to identify whether "controls," either complete or partial, are available at some locations within the subsystems studied and whether they are contributing to some of the aspects quoted above towards improved manageability of the system.

Kalankuttiya Branch Canal - There are several obvious complete "controls" along the Kalankuttiya Branch Canal, and each duckbill weir is one of them. The design of the Kalankuttiya Branch Canal takes advantage of this aspect in the control of flow into the distributary canals. In addition to these, a natural rocky constriction located 2.8 km downstream of the tank was identified as the effective control over most of the first reach of the canal. The impact of this constriction was evidenced through the water surface profiles computed for different steady flow regimes through a mathematical flow simulation model of the branch canal.

Other "controls" have been utilized in the design of the Kalankuttiya Branch Canal in the form of the "weir-box" installed at the head of the distributary canals to assess the flow diverted. However, a survey indicates that only 30 percent appear to be operating under hydraulic conditions capable of providing complete control. Partial control might be possible in 40 percent of them, hence limiting the reliability of the water flow assessment at the offtakes.

Degradation of the "controls" and occasional submergence was observed for various reasons, some of which are: temporary closure of a distributary canal downstream of the head to restrict'the command area cultivated during the dry season, littering of a downstream culvert, siltation of the distributary canal, etc. Total loss of the "controls" initially present results from destruction by the farmers of the weir in the weir-box (15%) and/or permanent submersion of the weir (15%).

Rajangana Pilot Area - Similar "controls" exist along the pilot distributary canal in the form of 3 duckbill weirs constructed to provide level control in the distributary canal and thereby flow control into the field canals. Baffle distributors or "modules" are installed at the head of each field canal and at the head of the pilot distributary canal itself. The "modules" provide additional "controls" provided that their installation and .operational specifications have been respected. "Modules" consist of precast, standard hydraulic devices providing complete control associated with a particularly steep head-discharge relationship that renders the flow diverted relatively insensitive to head variations within an acceptable range (Figure 11.17).

Santo Domingo Area Main Canal - The design of the SDA Main Canal does not provide "controls" as such for the diversion of water into the major Lateral canals. Instead, this was supposed to be achieved through the combined operation of gates at the cross-regulator and at the offtake. But there has been an intention to have some means of raising the water level through the provision of 35 "checking" opportunities along the main canal that permit the minor canals to abstract water directly from the main canal.

Partial "controls" were apparently envisaged in the design as indicated by the provision of Parshall Flumes at some key locations: the head of the main canal and at the heads of the laterals. But careful observations indicate that several flumes (Headgate flume, Lateral G) are either frequently or permanently submerged (Lateral F) and unable to perform as complete "controls." The NIA Water Measurement Table, which is used to compute flow through the flumes, provides correction factors to be applied to compensate for different degrees of submergence.

Kirindi Oya Right Bank Main Canal - There are no real "controls" along the Kirindi Oya right bank main canal but some exist at the offtakes for the purpose of assessment of flow. But many of them provide only partial control if any. The Irrigation Department intends to gradually replace the existing standard weir-box cum baffle-wall which has been found to be unsatisfactory, with another type of "control," a modified Broad-Crested Weir (BCW).

Preliminary conclusion: The design of the Kalankuttiya Branch Canal as well as the Rajangana Pilot distributary canal provides a number of hydraulic "controls." This indicates a clear and systematic intention of the designer to harness these hydraulic features to provide more control of the water delivered at the offtakes.

Control of the water surface profile in the parent canal and judicious locations of the offtake in accordance with the profile appears to be a stumbling block towards achieving the distribution objective whilst simultaneously relieving the burden of the operator.

In the case of the Kirindi Oya Right Bank Main Canal and the SDA Main Canal, the search for operational flexibility on the main canal prevails.

In these systems, "controls" are provided by designers for the main purpose of assessing the flow delivered at the offtake and monitoring. Monitoring appears, at least at Kirindi Oya, as the principal thrust towards achieving the distribution objective. But this implies more intensive human interventions and increased burden for the staff if it is going to be implemented.

CHAPTER III

ORGANIZATION AND DECISION MAKING FOR MAIN CANAL OPERATIONS

3.1 INTRODUCTION

This section describes and analyzes the organizational framework and the decision-making processes that are central to the management of the main canal in three case studies - the Kalankuttiya Branch Canal of the Kalawewa Left Bank in System H of the Mahaweli Authority of Sri Lanka, the Kirindi Oya Irrigation and Settlement Project under the Irrigation Department and the Ministry of Lands in Sri Lanka, and the Santo Domingo Area (SDA) of the Upper Pampanga River Integrated Irrigation System (UPRIIS) of the National Irrigation Administration (NIA) in the Philippines.

Managing any irrigation system are individuals exercising control at different points. They are members of a formal organization comprising a hierarchy of levels. Within this framework are managers at each level entrusted with certain functions, the performance of which will entail decision making regarding the management of the physical system towards achieving its goals, objectives, and targets. This decision making is influenced by the following key issues - the information available to the management at each level of the organization, the messages communicated between the levels, and the monitoring of the effectiveness of performance of the management based on this information. Further, in this study we will examine the implications when the physical layout fits the organization managing the irrigation system and when it does not. An additional issue to be explored is the impact of the decentralized or centralized nature of this organization on the operation of the main canal. Decentralization is defined as a method of organizing that disburses power and authority for decision malting to multiple levels in the organization while a centralized organization concentrates this at the top of the hierarchy.

3.2 THE FORMAL ORGANIZATION

3.2.1 Galnewa Project: Kalankuttiya Branch Canal

The Galnewa Project is managed by the Mahaweli Economic Agency (MEA) of the Mahaweli Authority of Sri Lanka (MASL).

Heading the central administrative hierarchy is the Director General of the Mahaweli Authority of Sri Lanka (see Figure III.1). The Mahaweli Economic Agency is one agency under the MASL and is responsible for settlement of farmers and the management of the irrigation system. To perform these tasks the MEA must work in liaison with its sister agencies, in particular, the Water Management Secretariat.

At the MEA (see Figure III.2), Project Coordinators are in charge of the different areas of the Mahaweli Project known as Systems. The Galnewa Project is located in Mahaweli System H (Figure III.3). From the perspective of control over the water resource at Kalankuttiya Branch Canal, at this level, the diversion at Bowatenne becomes significant. The Bowatenna complex is managed by the Headworks Administration, Operations and Maintenance Division of the MASL which is responsible for controlling the sluice at this point. This has a direct impact on storage at Kalawewa. This organization as seen above results in a complex multifunctional hierarchical organizational setup at the central level and this is replicated at the field level too.

Systems are divided into projects, each under the supervision of a Resident Project Manager with supporting staff (see Figure III.4). Projects generally cover an area of 8,000-12,000 hectares (ha). At this level, the Flow Monitoring Unit evaluates the performance of the administrative level below on the basis of the water duty.

Each project is in turn divided into administrative blocks, covering about 2,000 ha under the supervision of a Block Manager. At the command area of the Left Bank at the Galnewa Project there were three Administrative Blocks prior to January 1988 and only two thereafter. A Block Manager is assisted by various specialized officers as shown in Figure III.5. Each Block is further subdivided into units, each covering approximately 250 ha, under a Unit Manager who is assisted by two specialists, for water management and agricultural extension.

Prior to January 1988, there was a correspondence between the physical layout and the management, when the Kalankuttiya Branch Canal was managed by the Kalankuttiya Administrative Block, (Figure III.4). The official decision-making apparatus in control of the physical system is shown in Figure III.5. The Irrigation Engineer is responsible for water management in the whole block from the tank to the field channels. His other duties include contract supervision, building maintenance, labor management, and preparing budgets for construction and maintenance. Under him are Engineering Assistants who are responsible for construction and maintenance of the irrigation structures, including roads and culverts, water management, and making estimates for irrigation works. Below the Engineering Assistant is the Technical Officer whose duties include supervision of construction and maintenance, camp maintenance, labor supervision, and water management. Below the Technical Officer is the Irrigation Laborer. Two Irrigation Laborers operate the Branch Canal from the main sluices to the distributaries under the instructions of the Technical Officer.

In January 1988, the organization as described above, underwent a change. As a result of administrative reorganization, the ME4 abolished the Kalankuttiya Administrative Block. The command area under the Kalankuttiya Branch Canal was divided between the two remaining Blocks. The head end of the Branch Canal became the responsibility of the Irrigation Engineer, Galnewa and the tail end that of the Irrigation Engineer, Meegalewa. As part of the new institutional arrangements, the Left Bank Main Canal Unit (Figure IV.6) was created to coordinate water issues between the remaining Blocks which were now jointly responsible for the management of the Kalankuttiya Branch Canal. The most recent reorganization of the administrative arrangements with reference to the Kalankuttiya Branch Canal is the redefinition of the boundaries of authority for the Left Bank Main Canal Unit, the underlying principle being that if more than one administrative block has to share the water delivered by the physical system, it is a conveyance system and comes under the control of the Left Bank Main Canal Unit. The Engineering Assistant heading this unit are responsible for the operation and maintenance of the Main Canal. By this definition, the Main Canal Unit is also responsible for controlling the offtakes to the distributary channels in the Galnewa Block as they are direct offtakes from the Main Canal.

The Ralankuttiya Branch Canal is divided into five irrigation zones (305, 306, 307, 308, and 309). Distributary channels off the branch canal are labeled, for example 305-D1, which means the first distributary in irrigation zone 305. The range of the number of field channels along distributaries is 2-23. Field channels in turn may irrigate 6 to 23 farm allotments, though the average is 10 field allotments per field channel.

Superimposed on this physical system are the Administrative Units, originally eight in number and presently five. Each is under a Unit Manager assisted by an Irrigation Laborer for Water Management and a Field Assistant for agricultural extension. At the distributary, water management is the responsibility of the Unit Manager.

3.2.2 Kirindi Oya Irrigation and Settlement Project: Right Bank Main Canal

The Kirindi Oya Irrigation and Settlement Project (KOISP) is managed by the Irrigation Department. The organizational setup of the project (Figure III.6) is typical for a construction project of the Irrigation Department. A description of the tasks and responsibilities of the staff in a construction project in general is Riven in the Irrigation Department Manual (Irrigation Department, 1984).

The project is headed by the Chief Resident Engineer, who is responsible for the ongoing construction of phase II as well as for the water management and maintenance of the whole project. During the construction period the Chief Resident Engineer is assisted by four Resident Engineers; the Resident Engineer Head Works, the Resident Engineer Right Bank, the Resident Engineer Left Bank, and the Resident Engineer Rehabilitation. Listed below are their responsibilities with respect to water management as well as to the Water Management Feedback Center that functions directly under the Chief Resident Engineer.

The Resident Engineer Head Works. The Resident Engineer Head Works is responsible for the actual operation of head sluices through which water is issued from the reservoir into the main canals. The quantities and timing of these issues have to be authorized by the Senior Irrigation Engineer of the Water Management Feedback Center.

The Resident Engineers, The Resident Engineers, Right Bank and Left Bank are responsible for the actual canal operations in the command areas of the Right Bank and Left Bank main canals; this refers to the structures in the main canal, and offtakes to distributary and field canals. These operations have to be in accordance with the operational plans that are derived by the Resident Engineers from the water schedules as prepared by the Water Management Feedback Center.

The Water Management Feedback Center. Allocating water to the main, distributary, and field canals is planned by the Water Management Feedback Center, based on assumptions with respect to the demands of the water users and the estimates of the supply from the reservoir. The assumptions with respect to the demand side are based on calculations of the crop water requirements, that include estimates of evapotranspiration, rain, seepage losses, conveyance losses, water use during land preparation, percolation rates, etc. Water users and Resident Engineers are not involved in this water scheduling process. The water schedules that result from these calculations are sent to the Resident Engineers, who are assumed to operate the structures in their command areas conforming to these schedules (by calculating the required gate openings).

Apart from this scheduling the Water Management Feedback Center is expected to monitor the actual water issues through the offtakes from the main and distributary canals, and through the feedback of the daily measurements of these issues by the staff of the Resident Engineer Right Bank. Measurements of certain parameters that are used for the calculations of the water schedules, like seepage losses, rainfall, percolation rates as well as the establishment of rating curves for the calibration of the measuring structures in the whole system are the responsibility of the Water Management Feedback Center.

Administratively, the Water Management Feedback Center has no responsibility with respect to the operations in the whole system. Technically, however, it has the complete responsibility for the allocation of water to the different hydrological subsystems. As the Resident Engineer Right Bank's staff has been concentrating on construction activities during maha 1987/88, at the expense of water management, the Water Management Feedback Center was delegated "the full authority with respect to the operation" in the system, while the operations staff remained under the Resident Engineer Right Bank, both technically and administratively. This led to confusing situations as will be shown later.

3.2.3 Upper Pampanga River Integrated Irrigation System (UPRIIS): Santo Domingo Main Canal

The National Irrigation Administration (NIA), with headquarters in Manila, is in overall control of the policies, planning, and personnel of the Santo Domingo Area (SDA) command area. It is a single-interest bureaucracy in the business of delivering water. It is a decentralized organization where power and authority for decision making with reference to managing the water resource rest with the Project, and is done in participation with the farmer organizations or Irrigator Associations below the lateral. Between the NIA at the top and the ditchtender sections at the bottom are four other key levels of organization: the project, the district, the zone, and the division. (Figure 111.7).

The Santo Domingo Canal is located in District 1 of the UPRIIS Project. Management at this level is headed by a District Chief and his principal task is to supervise the area programmed for a cropping season (Figure III.8). In performing this task he is itssisted by a number of task specialists as well as general administrative staff for accounting and general administration. The Operations Engineer and the Hydrologist are the key task specialists. The former is a civil engineer and the latter an agricultural engineer: both are on the payroll of the District Administration and perform tasks within the boundaries of the District.

The Operations Engineer is responsible for the overall operation of irrigation systems' in the District. He supervises and coordinates operations of the irrigation systems as performed by the three zone engineers under him.

The Hydrologist as given in the organization chart is immediately below the Operations Engineer and is the representative of the Water Control Coordinating Centre (WCCC) at the District level. He establishes and ensures a targeted volume of water for his District and acts as liaison between the WCCC and the District. He is assisted by a group of minor officials known as gatekeepers.

The next organizational level is the zone, and the Santo Domingo Canal is located in zone 3. At this level a Zone Engineer is responsible for operation and maintenance of the irrigation network under him and for the timely supply of water to the command area. In these tasks, he is assisted by minor officials also known as gatekeepers.

Each zone is composed of a number of divisions and this'is under the management of the Water Management Technician (typically a division is a lateral, but a large lateral may be under the charge of more than one such technician) who is assisted in his tasks of operation and maintenance by ditchtenders who are in turn responsible for the smallest unit of management, the division.

3.3 DECISION MAKING

In each of the three cases, our focus of study is the following: the Kalankuttiya Branch Canal; the Kirindi Oya Right Bank Main Canal; and the Santo Domingo Main Canal. From this vantage point, in order to examine decision making associated with these canals in an effective manner, we must locate the effective boundaries of analysis, first, at the levels of decision making associated with the control of the water resource and second, at the interface from above as well as at the level of the Main Canal. As a result of this, we have identified the following key levels of decision making for the three systems (Figure III.9) from the highest level to the lowest.

3.3.1 Mahaweli System H: Galnewa Irrigation Project

The Mahaweli/Polgolla Dam: The Water Management Panel at the Mahaweli Authority of Sri Lanka office in Colombo makes the decisions regarding the allocation of the water resources of the Mahaweli River Project taking into account first, the demands of hydropower and irrigation and then, the issues for irrigation between the different Systems. The membership of this Panel includes representatives from the MASL, the MEA, the. Water Management Secretariat, the Ceylon Electricity Board, as well as representatives from the Irrigation Department and ministerial representatives from the political realm. Its function is to discuss and approve the Seasonal Operating Plan for a cultivation season.

Decision making is guided by two computer models at the macro- and micro-levels. The macro model is system-wide and takes into consideration policy options between allocating water for irrigation and hydropower. The micro model was developed for use in System H and is for the simulation of irrigation scenarios only - for evaluating the response of the system, tank, and canals in irrigated areas.

Once the cultivation season begins, problems may interfere with water issues, as for example, in 1986/87. Mechanical problems limited the anticipated diversions from the Mahaweli River to System H. This necessitates a weekly review of the situation and changes being made in the volume of water to be issued. The forum for making decisions is the weekly meeting between the Chief Irrigation Engineer of MEA and representatives of the Water Management Secretariat.

<u>Kalawewa Reservoir: The System H Water Management Coordinating Panel</u>. The System H Water Management Coordinating Panel controls water issues from the Kalawewa Reservoir. This panel comprises the Deputy Resident Project Manager (Water Management), Galnewa Project, Chairman; the Irrigation Engineer, Flow Monitoring Unit, Galnewa, Secretary; and the Irrigation Engineers responsible for the main sluices of the reservoir.

The functions of the panel are: 1) to discuss and decide weekly sluice issues, taking into account the availability of water; 2) to insure, with assistance from others, that only the allocated quantity is taken from the reservoir and is distributed properly within the irrigable areas: 3) to increase efficiency by varying diversions within the system; 4) to submit data regarding reservoir levels, sluice issues, rainfall, and inflows into the system on a daily basis through the secretary of the p e l to the Chief Irrigation Engineer, MEA, who upon presenting the situation to the Water Management Secretariat, would then obtain the required diversions into the system; and 5) through the secretary of the p e l , to maintain close contact with the Bowatenna complex and bring to the notice of the Chief Irrigation Engineer any problems regarding diversions.

Water issues are limited to the command area sanctioned under the Seasonal Operating Plan. Initial water issues are based upon the extent of land prepared during the land preparation period as allocated in the cultivation calendar. Subsequently, for each rotational issue there is a standard allocation of water for the total extent under cultivation. A further computation is made for seepage and percolation (5 percent) and for conveyance losses (10 percent) in the command area and the main canal.

Losses at the level of the distributary channel are discounted as they are assumed as seepage on the farm.

The secretary to the committee explained the role of the panel thus:

> The subject of discussion at these meetings was operations (for water management) for the upcoming week in the H area. The official in charge of the management of a particular section of the main system is responsible for presenting the relevant details regarding rainfall and stage of crop growth, and indicating how much water is required for his area. The Irrigation Engineer (Flow Monitoring Unit) is responsible for submitting information on rainfall in the Kalawewa catchment, water through diversion, and the balance in the tank at the end of the previous week. Based on this information a decision is made on how much to issue at the field level, with an eye towards stretching the water until the last issue for the season as decided upon at the cultivation meeting at the beginning of the agricultural season. A decision is also made regarding the amount to be issued to each sluice for the next week. The distribution of this amount within the project is the function of the operating staff. So long as they do not exceed the weekly average, they can decide whether to distribute the given amount of water in two or five days, or to reduce issues if there is adequate rainfall. In addition, these meetings are also a forum for reviewing the previous week's operations from the perspective of how decisions were implemented with reference to the decisions made. Underlying these operations is the assumption that canal control of water issues alone is not enough, that the efficient distribution of water within the block is important, and that this can be achieved only with the cooperation of block-level officials such as the block Irrigation Engineer and his engineering assistants as well as the farmers.

This committee was created in January 1987 in response to the drought and the resulting sharp drop in the reservoir level. It held regularly scheduled weekly meetings and performed its functions systematically. However, in yala (dry season) 1988, possibly due to the less acute situation in reservoir levels, meetings were less frequent. Nevertheless, the secretary to the panel continued to act with committment and efficiency, as liaison with the higher level of management.

Kalawewa Left Bank Main Canal: Office of the Resident Project Manager, Galnewa. Prior to the administrative reorganization in 1988, Kalawewa Left Bank Main Canal was the principal conveyance system delivering water to three administrative blocks in the Galnewa Project (Figure III.10). These are Galnewa, Meegalewa, and Kalankuttiya. The Deputy Resident Project Manager (Water Management) Galnewa Project, is in overall command of the Left Bank under the coordination of the Resident Project Manager, Galnewa. A water issue schedule at this level is based on the acreage to be irrigated for the Left Bank as sanctioned by the Seasonal Operating Plan. In consultation with the Irrigation Engineers at the Administrative Block, the Deputy Resident Project Manager estimates the water requirements of the respective blocks, adds it together with an additional 25 percent for conveyance loss, and makes his request for the Left Bank from the System H Water Management

Coordinating Panel. Maha 1986/87 (wet season) illustrated the consequences of failure of the conveyance system to deliver what is allocated to Kalankuttiya administrative block (Raby and Merrey, 1989) under drought conditions. This was due to the absence of a systematic management to control and monitor water allocations to the administrative blocks along the Left Bank Main Canal.

In yala 1988, despite the new institutional arrangements, management of the Kalankuttiya Branch Canal continued much as before. The Kalawewa Left Bank Main Canal Unit was not involved either in Kalankuttiya tank sluice operations or its Branch Canal operations. The Irrigation Engineer Galnewa with the assistance of an Irrigation Laborer under him set the Kalankuttiya Tank sluice daily discharge to the Branch Canal, as well as the daily settings of the Distributary Canals in the section of the Branch Canal under him. In the section of the Branch Canal under the Meegalewa Administrative Block, the management was in the hands of an Engineering Assistant who had previously also managed this section as an Engineering Assistant in the defunct Kalankuttiya Administrative Block in consultation with the de facto managers of the upper section of the Branch Canal.

The role of the Main Canal Unit was limited to ensuring that the tank level at Kalankuttiya would not fall to a level where it would be unable to make issues to the Branch Canal. A Technical Officer at the Main Canal Unit who was responsible for the sluice operations of the Kalankuttiya Main Canal under the previous management was entrusted with this task to be performed in cooperation with the Engineering Assistant Main Canal Unit and the Irrigation Engineer Meegalewa.

A redefinition of the boundaries of the Main Canal is planned for the future. If previously, the Kalawewa Left Bank Main Canal extended from Kalawewa Reservoir to Mulannatuva Tank and from there to the Meegalewa Block, now it would include the physical system up to Mulannatuva and then diversions from this tank to Kalankuttiya Tank and then to what was Kalankuttiya Branch Canal up to the point of the administrative boundaries between the two blocks that manage the Branch Canal. The Engineering Assistant heading this unit will be responsible for the operation and maintenance of the Main Canal. By this definition, the Main Canal Unit is also responsible for controlling the offtakes to the distributary channels in Galnewa Block. Moreover, the Flow Monitoring Unit will perform its role of monitoring through measurement along the Left Bank Main Canal as well as along the Branch Canal no.1.

The decision-making processes resulting from this change in hydrological boundaries was explained by the Irrigation Engineer (Flow Monitoring Unit) as follows: The System H Water Panel will allocate water to the Left Bank on a weekly basis. The Block Irrigation Engineer will attend these meetings as observers so that they will, know and understand on what basis the panel allocates water so that they can make their requests from the main canal unit, on the same basis. The Block Irrigation Engineer will request the required amount of water from the Engineering Assistant, Main Canal Unit who will then total the amount fcir the command area and request this from the Panel. Based on what the Panel allocates and what is requested by the respective Irrigation Engineers, the Engineering Assistant will prepare an irrigation schedule for the Left Dank. In the event of problems or shortages, he will consult with the Project Engineer, Left Bank (formerly known as Deputy Resident Project Manager).

The Flow Monitoring Unit at Galnewa monitors the water use of thr Administrative Block in terms of the monthly water duty. Blocks are compared against the performance of other Blocks as well as against their own targeted values under the Seasonal Operating Plan. A monthly report is submitted to the Mahaweli Economic Agency as part of its monitoring operations.

Kalankuttiya Branch Canal: The Block Offices at Kalankuttiya, Galnewa and Meegalewa. Prior to January 1988, at the Branch Canal, the Irrigation Engineer had divided the water he had received, supplemented with what was already available in the tank, equitably among the 20 Distributary Canals offtaking from the Branch Canal. He had a distribution schedule based on the irrigated command area and crop water requirements. However, dependine on what was available in the Kalankuttiya Tank he adjusted this schedule. Thr weekly block meeting where he meets the Unit Managers is the forum for the Irrigation Engineer to evaluate the weekly operational water schedule. Water duty is computed for each Distributary and comparisons are made between original targets based on the irrigated command area and the standard weekly crop water requirements of 2.5 inches [63.5 millimeters (mm)] and actual usage. The Unit Managers are informed of any changes in the irrigation schedules and the latter may also brine up any additional requests for water. This is normally done as an extension of a rotation. Maha 1986/87 illustrated cases where the expected amount of water was not conveyed to Kalankuttiya Tank and as a result, the Irrigation Engineer and his staff were forced to draw from the tank till it reached dead storage. A similar situation has not arisen in yala 1988.

Distributary offtake: The Unit. At this level, though there is some correspondence between control of distributary offtake and control of unit. this is not always the case. In Kalankuttiya there are cases where the control of the distributary offtake is in the domain of one unit manager hut the water issues are common to two units. This will at times cause complexity in the tasks of delivery and issue of water at this level.

As documented for 1986/87, at the Unit, the Irrigation Laborer of the Block Office who is in charge of the head of the distributary, the Unit Manager, the Irrigation Laborer. of the Unit, and the farmers and their leadership in some cases try to adjust what is perceived by management and farmers as an inadequate supply by extending the 7-day rotation to 10 or 12 days and beyond (Raby and Merrey, 1989). This necessitated some additional requests for water from the management level at the Left Bank.

The Unit, Manager receives his information on water schedules from the Block Office, hut he implements; this schedule through the Irrigation Laborer. He has standing orders on the amount of water he must issue as determined by the height of the staff gauge at the head of the distributary. The typical Irrigation Laborer at the Distributary offtake at Kalankuttiya is a local resident, himself a cultivator and has on the average, 10 years of service and manages the distributary offtake as well as distribution at the field channel turnout based on his experience and farmer demand. But this is not always the case; the Unit Manager is expected to keep him informed of decisions made at the Block meeting and the Irrigation Laborer is expected to discuss problems with reference to water issues. More typically, the Irrigation Laborer may take up issues of shortages with his counterpart at the Block or the Engineering Assistant responsible for water management at the Block. Commonly, however, the Irrigation Laborer will submit his request to the Block through a note from the Unit Manager validating his verbal demand. A supply based plan thus becomes demand driven.

Preliminary Conclusion: Impact of Organization and Decision Making on Canal Operations

A corollary to the size of the Mahaweli Project is its centralized apparatus of organization/decision making. The planning and the subsequent adjustments of the simulated plan for seasonal operations at the Galnewa Project are undertaken at the Center in the hands of the Mahaweli Authority of Sri Lanka. During the course of the season, the operational plan in real time as well as its adjustments are dependent again on the Center, but now in the hands of two members of the Mahaweli family of agencies - the Mahaweli Economic Agency and the Water Management Secretariat. The density of management between the unit of study (the Kalankuttiya Branch Canal) and its water resource (Polgolla Dam) is reflected in the number of agencies (4), the number of levels (4) and finally the number of individuals involved in decision making through whom information must be accessed above Galnewa Project (Figure 111.11). This is categorized as the number of interest groups and individuals participating in decision making related to the water resource. This centralization and density make for complexity of management in terms of response time to fill the Kalawewa Reservoir. This becomes problematic particularly in a water-short season. The availability of telephone and radio communication facilities with the levels above makes for some ease in this situation at Galnewa. But the nonavailability of similar communication facilities between the Project and the levels below makes for difficulties in communication.

At the Galnewa Project, the nature of the apparatus for organization and control of the sluices of the Kalawewa Reservoir is single interest and is therefore simpler and when control is exercised, as in the drought-ridden period in 1986/87, the Water Management Coordinating Panel is an effective mechanism.

Below this level, while the agency remains the same, complexity is the result of the number of decision centers influencing decision making at the Block - originally the three Block Offices at Galnewa, Kalankuttiya and Meegalewa and subsequently, the Main Canal Unit with Galnewa and Meegalewa (3). At the Unit any such complexity in communication is the result of (a) sharing of the Distributary Canal offtake between two Units and (b) communication between the Unit Manager and his Irrigation Laborer. Communication for operation is largely informal and verbal, supplemented by the periodic meetings for progress evaluation of the cultivation plan.

The object of monitoring is the water duty based upon water issue/supply compared with the seasonal target under the Seasonal Operating Plan for the System; for the Left Bank/Project; for the Block; and for the Distributary as implemented through the standing orders. But canal operations during a cultivation season are in fact demand based. Further, at the unit level, in emphasizing the multiple aspects of the performance of a unit manager, for example, are health or housing for the settler, or operation, maintenance or construction in the case of the Irrigation Engineer. There is actually a trade-off in the emphasis given to the water management function of a Unit Manager. At the level of the Irrigation Laborer there is a complete absence of monitoring of his performance and he manages the Distributary Canal off-take based on his experience and the information he may receive on an informal basis.

3.3.2 Kirindi Oya Irrigation and Settlement Project: Right Bank Main Canal

Broadly three levels of decision making can be recognized in the Kirindi Oya Irrigation and Settlement Project. The highest level is the Senior Irrigation Engineer of the Water Management Feedback Center, as he controls the water issues from the head sluice. The Resident Engineer Head Works, whose staff operate the Head Works, can be considered at the next level as he only implements the decisions of the Senior Irrigation Engineer. The third level is the office of the Resident Engineer Right Bank in which the Resident Engineer Right Bank himself, the Irrigation Engineer and the Technical Assistant are all involved in the supervision and monitoring of the canal operations. Due to the fact that all of them were more occupied with construction activities, their involvement with water management has been at a minimum and a separation of their responsibilities would not reflect the actual situation. The lowest level of decision making is that of the Irrigation Laborer who actually operates the different structures.

The Water Management Feedback Center and the Resident Engineer Head Works. The responsibility of the Senior Irrigation Engineer of the Water Management Feedback Center with respect to canal operation is not very clear. Whereas the Senior Irrigation Engineer till June 1988 did not have formal responsibilities with respect to canal operation, he was expected to monitor the actual water issues and the canal operation. As the Resident Engineer Right Bank's staff was very involved with construction activities, an informal arrangement was made so that the Senior Irrigation Engineer could give instructions to Irrigation Laborers, who were administratively under the Resident Engineer Right Bank's office. In June 1988, this informal arrangement was formalized through a letter from the Chief Resident Engineer in which he delegated the "full authority over the operation" to the Senior Irrigation Engineer of the Water Management Feedback Center. However, no reference was made to any means by which to effectuate this full authority and in practice, no means whatsoever were allocated for this purpose to the Senior Irrigation Engineer.

The informal as well as the formal arrangements were not well defined; the Senior Irrigation Engineer's authority was sometimes openly questioned by the Irrigation Laborers. Thus the actual canal operation has been rather chaotic during maha 1987/88 and yala 1988, as nobody was really responsible for the canal operation. Monitoring of the canal operation by the Senior Irrigation Engineer and his staff sometimes led to direct instructions by the Senior Irrigation Engineer to the Irrigation Laborers, and in other cases led to letters from the Senior Irrigation Engineer to the Resident Engineer Right Bank concerning the canal operation.

The actual allocations from the reservoir have to be authorized by the Senior Irrigation Engineer of the Water Management Feedback Center. In practice, this means that if a substantial change of the discharge in the main canal will take place, the Senior Irrigation Engineer sends a note to the Resident Engineer Head Works, with a copy to the Resident Engineer Right Bank. In this notification he mentions the date of the envisaged change, the envisaged new discharge itself: and a request to the Resident Engineer Right Bank to alert the Irrigation Laborers to the envisaged change. The operations of the structures are then done by the staff of the Resident Engineer Right Bank.

Several standing orders of the Irrigation Department apply to the operation of water flows in the main canals of the Kirindi Oya scheme:

1. Upstream of a cross-regulator, the level of the main canal always has to be maintained at full supply level. In this way a stable discharge can be supplied through the offtakes to the distributary canals.

2. If the discharge through the main canal increases, the excess discharge has to be released gradually through the gates of the cross-regulator.

3. The released discharge has to be spread evenly over the parallel gates of the cross-regulator to prevent erosion of the canal bund, and to extend the life of the cross-regulator.

In the opinion of the staff of the Kirindi Oya scheme these standing orders are sufficient for proper operation of the main canal provided the Irrigation Laborers have some experience in these operations.

Because of some lacunae in the quality of the construction of the downstream developnent of the Kirindi Oya scheme and because of a higher percentage of upland soils in the command area than assumed before the construction, the full supply depth does not give enough head to issue enough water through the distributary canal offtakes during land preparation. Thus it is necessary to raise the levels in the canal (in some cases with 12 centimeters) during land preparation through overflowing of the side walls of the cross-regulators, A permanent overflow is necessary in some cases where the required head cannot be reached at all.[1]

In these cases the first decision to operate the canals in this particular way was taken by the Resident Engineer Right Bank, whichever way

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[1]During the off-season between yala 1988 and the coming maha season, the side walls of the cross-regulators were planned to be raised to correct the faulty full supply depths.

they were applied, with the consent of the Senior Irrigation Engineer of the Water Management Feedback Center. In some instances, however, the Senior Irrigation Engineer has taken the initiative for a new instruction with respect to the operation of the structures in the main canal of which two examples are given below:

1. With rainfall, the discharge through the main canal increases mainly because some Irrigation Laborers reduce the discharge to their distributary canals. For that reason, the discharge that is released from the head sluice is usually reduced (on the instruction of the Senior Irrigation Engineer) by 5 to 10 cusecs (0.142 to 0.283 m^3/sec, but in case of heavy rain (more than 75 mm in the whole command area of the Right Bank Main Canal) the discharge may be stopped entirely for 5 days. If the discharge is restarted after a heavy rain, the Irrigation Laborers (probably on request of the water users in their distributary canals) tend to keep water as much as possible for their own distributary canals, which delays the conveyance to the tail-end tracts. To solve this problem the Senior Irrigation Engineer has instructed the Resident Engineer Right Bank to refrain from operating the cross-regulators after a heavy rain, in order to stabilize the main canal sooner after the rain (even if that means that the cross-regulators will overflow).

2. Another aspect of the canal operation that has been taken up by the Senior Irrigation Engineer is the aggravation of the destabilization caused by the cleaning of the siphon. The entrance of the siphon is equipped with a grill, to prevent human beings being pulled into the siphon. Every morning the grill is cleaned, and the resulting decrease of friction causes a daily drop of the level in the main canal upstream of the siphon by approximately 0.45 meters. The Senior Irrigation Engineer has signaled the problem as it also increased the risk of overtopping of the main canal upstream of the siphon, and advised the Resident Engineer Right Bank to remove the grill, and to install a fencing of barbed wire around the entrance of the siphon.

Little information is available to the Senior Irrigation Engineer regarding the actual behavior of the main canal. The discharges in the main canals and distributary canals are not reliably known (only the discharge released through. the head sluice is reliably known). The information that the Senior Irrigation Engineer will get with respect to the behavior of the main canal is through the incidental information about problems that occur- for example, the overflowing of the main canal or the drainage of excess discharge through Branch Canal 2. Daily information on variations in flow and its consequences through feedback from Irrigation Laborers or water users will not reach the Water Management Feedback Center as that information goes to the Resident Engineer Right Bank's staff. Only indirect information through feedback of the measurements by the staff of the Resident Engineer Right Bank will reach his office.

This feedback system is not reliable as no cross checks are made any more and because many measuring structures have been damaged (as well as because of the frequent backwater effect, as will be pointed out in Chapter 4). A cross check system, consisting of an Irrigation Laborer who recorded separately all water issues, has been operational during 2 to 3 months for the Right Bank, but appeared to be unreliable and was abandoned by the

Resident Engineer Right Bank's staff. Monitoring of the actual canal operation is done, therefore, through frequent field visits by the staff of the Water Management Feedback Center.

It is clear from the above that the monitoring done by the Water Management Feedback Center and the information available to them are not appropriate to regulate the main canal. Delegating "full authority for the operation" to the Senior Irrigation Engineer without making available such information to him or allocating in some other way the means that are needed to carry out this responsibility is hot very practical.

The Resident Engineer Head Works can be considered to be of the same hierarchical level of decision making with respect to the canal operation and the operation of the head sluice. He is assisted by a Technical Assistant in the actual operation of the head sluice. The Resident Engineer Head Works receives instructions from the Senior Irrigation Engineer to increase and decrease the discharge to the main canal. He calculates the opening discharge and gives instructions to a Technical Assistant, who operates the head sluice.

<u>The office of the Resident Engineer Right Bank</u>. In the office of the Resident Engineer Right Bank, the Resident Engineer himself, together with the Irrigation Engineer and the Technical Assistants are involved in the decision-ding processes with respect to canal operation. At the same time, all these officers are involved in construction activities, so that canal operation receives relatively little attention. This led to the afore-mentioned arrangement with the Senior Irrigation Engineer of the Water Management Feedback Center.

At the beginning of maha 1987/88, the Resident Engineer Right Bank decided that 3 of the 15 Technical Assistants would be confined to the day-to-day operation of the 3 tracts of the Right Bank Main Canal. It was envisaged that this division of responsibilities would guarantee a better performance, compared to the earlier arrangement where all 15 Technical Assistants were involved with both operation and construction activities. Nevertheless, both arrangements did have the same result: operations were neglected. The 3 Technical Assistants who were assigned a tract each, felt frustrated that they were not allowed to be involved in construction activities at all; motivation was low for them to go to the field for their operational duties.

The overall responsibility for the operation of the Right Bank was delegated to one of the two Irrigation Engineers who was working for the Resident Engineer Right Bank's office (this Irrigation Engineer was allowed to combine the operation and construction tasks).

During maha 1987/88 and yala 1988, the Resident Engineer Right Bank did not delegate the responsibility for the conveyance of water to the tail-end tracts to a Technical Assistant, but did this himself in cooperation with the Irrigation Engineer who was in charge of operation and maintenance. As the Resident Engineer Right Bank himself and the Irrigation Engineer did not have the time to monitor the actual canal operations they did not have enough information to actually coordinate the canal operation. Operation of the main canal as a whole (i.e., the conveyance and distribution functions) was thus not coordinated in the field and water issues to the 3 tracts, the distribution function, were managed separately.

Irrigation Laborers who did not operate their structures correctly did not feel responsible for the consequences downstream. If they open or close the gates of a cross-regulator fully, without informing the Technical Assistant or the Irrigation Laborers downstream, the resulting excess discharge will cause problems downstream. The Resident Engineer Right Bank understands this problem and next maha he plans to charge the Technical Assistant of the tail-end tract with the supervision of the main canal. The problems of uncoordinated and suboptimal operation of the cross-regulators upstream, often lead to water shortages (or excess water) at the tail end and thus the Technical Assistant of the tail-end tract will be more motivated to coordinate the conveyance than other Technical Assistants. However., the easiest way to take care of the conveyance function is by asking for more water to be allocated to the main canal as a whole as it is done presently.

In principle, the Technical Assistants provide the basic instructions to the Irrigation Laborers. In case a substantial change of the discharge through the main canal is to take place, the Technical Assistant is expected to alert the Irrigation Laborers, although he does not always do it. In practice, his involvement in day-to-day water management is limited and his field visits are infrequent.

With respect to the changes in the discharges in the main canal, the Resident Engineer Right Bank's office is informed of the date of change, but not of the envisaged time., A change in the afternoon or evening requires, however, that the Irrigation Laborers be alert during the night. which they usually are not, especially if they are not aware of a change at all.

The Resident Engineer Right;Bank and the Irrigation Engineer also visit the field now and then, and give instructions to the Irrigation Laborers with respect to canal regulation. These instructions are made on an ad hoc basis; it has happened that the Technical Assistant and the Irrigation Engineer have given different instructions to an Irrigation Laborer on separate field trips within a short period of 5 minutes.

Irrigation Laborers have been instructed by the Technical Assistants to see that, in cases of heavy rain the discharge in the distributary canals does not become too large, because it would erode the canal. In such a situation they are expected to reduce the discharge and inform the Technical Assistant, who will inform the Irrigation Engineer. The Irrigation Engineer in turn requests the Senior Irrigation Engineer for a reduction of the main canal discharge. In principle, the excess discharge has to be drained through the spills (i.e., the radial gates) to 'the Weerawila Tank. In practice, the 'lack of coordination among the Irrigation Laborers and the Technical Assistants, or slow reaction by the Irrigation Engineer and Technical Assistants, led to the drainage of the excess discharge through Branch Canal 2. Branch Canal 2 anyway functioned as a drain for fluctuations in the main canal discharge,, thus decreasing the risk of the downstream cofferdam breaching, but it was perhaps also an easy way of dealing with problems of canal operation; reflecting that water management had a low priority compared to construction activities.

Because of this function of Branch Canal 2, special instructions were given for the operation of the cross-regulator just downstream of the offtake to Branch Canal 2. Irrigation Laborers were instructed to adhere strictly to full supply depth, because of the risk of breaking the cofferdam downstream of the cross-regulator. After the cofferdam breached on two occasions the Irrigation Laborers were threatened that they would be fined 2 days' salary if it happened again. As the main canal fluctuates considerably at Branch Canal. 2, due to its position downstream af a major part of the main canal including the siphon, the cross-regulator had to be operated quite frequently, even at night. The Irrigation Laborers who were working close to the cofferdam and the cross-regulator near Branch Canal 2 maintained an .informalinformation system to prevent breakage of the cofferdam.

<u>The Irrigation Laborers</u>. At this lowest level, decisions are made by the Irrigation Laborers concerning the operations of individual structures of the main canal cross-regulatoris and distributary canal offtakes. Usually, the Work Supervisor supervises the activities of the Irrigation Laborer. However, during maha 1987/88 and yala 1988 the Work Supervisors were involved only in construction work and not in water management. Next maha, they will be involved in water management too. With respect to canal operation the Irrigation Laborers have to follow the afore-mentioned standing orders.

Maintaining full supply depth in the main canal requires regular interventions by adjusting the gates of the cross-regulators due to fluctuations in the discharge. Such fluctuations or changes of flow occur due to changes in the discharge issued through the head sluice, to operations of cross-regulators *or* offtakes upstream of the concerned cross-regulator, or to rainfsll.

According to the standing orders, any excess flow in the main canal has to be released gradually in order to stabilize the fluctuations in the downstream part of the main canal and this means that a change in flow has to pass through a cross-regulator while maintaining the head. As the Irrigation Laborer is not aware of the duration and size of a change in flow, the adjustment of the gates is a time-consuming trial-and-error process for him. If he does not release the!,discharge gradually, the fluctuations in the downstream main canal will increase. However, as these fluctuations of the discharge are drained through Branch Canal 2, there are no incentives for the Irrigation Laborer, Technical Assistant, and Irrigation Engineer to take care of these fluctuations as long as the discharge in the main canal is large enough.

. An exception to this is the operation of the cross-regulator at Distributary Canal 5 of tract, 1. On 11 June 1988, at 1330 h the discharge to the main canal from the head sluice, was increased by 0.425 m^3/sec (15 cusecs). As a result, the level of the main canal at Distributary Canal 5 started to rise, and the cross-regulator started to overflow. The Irrigation Laborer, who probably was not alerted by the Technical Assistant of the expected change in the discharge, opened the gates of the cross-regulator only at 2000 h. As he opened them totally, the level of the main canal upstream of the siphon (which is situated downstream of the cross-regulator of Distributary Canal 5) started to rise and the main canal over-topped.[2] Then the Irrigation Laborer would have an incentive to release the discharge gradually because he has to prevent overtopping of the main canal upstream of the siphon.

The policy of the Irrigation Department with respect to the operations of the main canal besides the 3 standing orders is to expect the Irrigation Laborers to become experienced on-the-job. To get this experience the Irrigation Laborer can be helped to some degree by supplying him with some quantitative information on expected changes in flow. In order to release a change of flow gradually, the Irrigation Laborer should have some sort of idea of the size and duration of the discharge as well as the envisaged change in discharge; the Irrigation Laborer cannot see at the beginning of the change of flow how big it will be and how long it will continue. If at all he is warned about the change of flow by the Technical Assistant, he is not informed about the quantitative dimensions of the flows. However, if he is informed about the latter, he could gradually get an idea of the sizes of discharges and the required reaction on particular changes.

The discharge through the cross-regulator is generally not spread evenly over the parallel gates. Usually, one gate is opened to a large extent and one or two others opened only slightly. The excuse of the Irrigation Laborers is that there is debris obstructing the other gates, or that the gates are not functioning well. A more probable reason is that the operation of all gates at a low opening is a heavy job because of the high water pressure, compared to the operation of only one gate at a low water pressure. Moreover, it is easier for the Irrigation Laborer to recognize the required opening for the standard discharge for one gate only, compared to the openings of a combination of gates.

In taking a decision concerning canal operation, the Irrigation Laborer has to consider the discharge that has to be issued to the distributary canal offtake, the distribution, as well as the water that has to be conveyed to the downstream parts of the main canal, the conveyance. With respect to the distribution, the Irrigation Laborer has to issue as much as possible to the distributary canals during land preparation, and is allowed to increase the head by overflowing the cross-regulator.

During the cultivation season, the Irrigation Laborer should follow the water schedules as prepared by the Senior Irrigation Engineer. However, the measuring structures of the distributary canals do not function yet, and thus the actual issuing of water to the distributary canals is a trial-and-error process. Moreover, it has to be a trial-and-error process, because he has to adjust the issues to the demands of the water users; the unofficial instruction of the Technical Assistant in this respect is to give as much water to

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[2]The Irrigation Department plans to solve this problem by raising the bunds of the main canal.

.the water users as they want (so that the Technical Assistants themselves do not have to spend time in dealing with requests for rater) and ask the leaders of the water-user groups for written requests. After land preparation is completed, the Irrigation Laborer reduces the discharge to a lower level, and gives more if water users request him for more. In practice, this 'trial-and-error process occurs after land preparation, till a situation is established which is reasonably satisfying for water users and Irrigation Laborers.

In general, the upper limit of this discharge. is the design discharge, even in periods of high water demand, . The only way to increase the water issues to the distributary canals during such periods is by increasing the head, and thereby overflowing the cross-regulators. If a constant level of overflowing of the. cross-regulator is maintained this practice will not interfere with the conveyance function. But if it is practiced as a method of adjusting the issues to the distributary canal, this practice is in conflict with the conveyance of water to downstream tracts. Due to lack of supervision of the conveyance through the main canal as a separate operational goal and the canal operation in general, this practice has been wide-spread during maha 1987/88.

As stated earlier, canal operation can be used by the Irrigation Laborers for 2 different and sometimes conflicting functions: the conveyance of water through the main canal and the water issues.to the distributary canals. As the water users are close by, and always demand water, the Irrigation Laborer usually gives priority to water issues to the distributary canal, and more *so* if the conveyance of water is not monitored.

With respect to the water issues to the distributary canals the Irrigation Laborers have to choose *among* the following options:

* If they can issue enough water to the distributary canals without going against the standing orders, they will probably do *so*, but will issue a certain extra discharge to allow against fluctuations.

* On the other hand they can also issue too much water anyway, to be sure that water users will not complain to them.

* If they cannot get enough discharge to the distributary canal, they can close the gates of the cross-regulator a little and allow a certain overflowing of the cross-regulator; whether temporarily, as they can always defend.their case to any supervisor by stating that the main canal is fluctuating (i.e., rising), .or permanently, if the water users claim that. they do no get enough water.

In all cases there is no. discussion, or any other form of information exchange, between the people that schedule the water issues and the water users, except for the malfunctioning devices used for actual water issues to the distributary and field canals. These allocation processes and the resulting operational plans, while assumed to be separate from the canal operation, do interfere clearly with the canal operation as explained above. Together with the trial-and-error processes for the release of the discharge through the gates of the cross-regulator, the trial-and-error processes for issuing water to the distributary canals cause a lot of fluctuations of the level of the main canal.

Recently, the Irrigation Laborers have been instructed not to operate the cross-regulators after the discharge in the main canal has been reduced because of rain. Thus it is hoped to realize a fast stabilizing of the main canal after the discharge becomes normal again. Many water users complain that even after sufficient rain has fallen, they do not want the discharge to be lowered as water does not remain longer than 4 hours on the upland fields. Moreover, as yet the Irrigation Department has no means of measuring the rainfall in the different parts of the scheme. When the discharge becomes normal again, all water users want to irrigate at the same time and the Irrigation Laborers at the head-end tract will have to close the gates of the cross-regulators, if the water users request them to do so.

Preliminary Conclusion: Impact of Organization and Decision Making on Canal Operations

Standing orders and unsteady flow conditions. Canal operation in the Kirindi Oya Scheme is governed mainly by the standing orders, together with some additional instructions. The management efforts by all officers are mainly directed to .the execution of these standing orders. The actual responsibilities of the Irrigation Laborer, and the options to tackle them are not fully covered in this way; the standing orders assume a fixed, supply-based water schedule that can be easily met by following these instructions because it assumes steady flow conditions. The actual water management is mostly demand driven without any adjustment of the operational targeting and thus unsteady flow conditions prevail.

Design and the actual fulfillment of the conveyance and distribution functions. Two different aspects complicate the decision making by the Irrigation Laborer. First, the actual decision making by the Irrigation Laborer is the dealing with trial-and-error processes with respect to the release of flows through his cross-regulator. Second, the issuing of water to the distributary canals also requires trial-and-error processes, which processes, however occur mainly at the end of the land preparation.

These two processes can be conflicting in some cases, but in such cases the present instructions to the Irrigation Laborers are not sufficient for operation of the main canal with respect to conveyance and simultaneous water distribution; there are many options that have not been covered. If the choices'among these options are left entirely to the Irrigation Laborers, it will lead to a suboptimal canal operation as: i) they will not recognize the exceptional (e.g., predictable change of flows) and therefore consider than as routine aspects of the canal operation, and ii) the Irrigation Laborers are not neutral decision makers with respect to the conflicting interests of the canal operation and water distribution.

The role of communication. At present, the situation is worsened by the fact that little communication takes place between the Irrigation Laborers and the Resident Engineer Right Bank's staff. Therefore, little feedback from the Irrigation Laborers' problems is possible, and instructions cannot be attuned to the actual needs: Because the Resident Engineer Right Bank's staff was not monitoring the canal operation satisfactorily, the Senior Irrigation Engineer felt compelled to monitor the canal operation to a certain degree. This inevitably led to conflicts between the Water Management Feedback Center and the Resident Engineer Right Bank's staff.

Organizational design solutions and non-solutions. During maha 1988/89, the situation may improve when the Technical Assistant of the Resident Engineer Right Bank's office who will be responsible for the tail-end tract .will become responsible for the canal .operation too, when he will have .to monitor the entire canal operation to get enough discharge at the tail end.

Further, if the Technical Assistant of the tail-end block prefers it, he will ask for more water in the main canal than is really necessary, to make his job easier. To prevent such a situation, higher levels in the organization will have to monitor the actual water distribution and conveyance as well.

Canal operation cannot be managed by the Senior Irrigation Engineer of the Water Management Feedback Center as long as he has no information on the actual consequences of canal operations. Even without much effort being exerted by the staff of the Resident Engineer Right Bank to operate the water flows in the main canal, because of their interaction with their own staff and the water users they were better informed than the Senior Irrigation Engineer on the actual behavior of the main canal. This means that even if the Senior Irrigation Engineer. had technical authority over the Irrigation Laborers, he would have been unable to operate the main canal without such real time information gathered form the Irrigation Laborers and water users.

In practice, the Senior Irrigation 'Engineer monitors water issues through the head sluice and the issues to the distributary canals (which will be possible from next maha). If the Technical Assistant of the tail-end block requests, through the Resident Engineer Right Bank, for more water to the main canal, the Senior Irrigation Engineer will not be able to refuse that request. He does not have sufficient insight into the actual water needs in the different tracts, and cannot take the risk of crops being destroyed through lack of water.

Improved procedures. The (quality of canal operation by the Irrigation Laborers can also be increased by giving them a knowledge of what happens in the main canal as well as in their distributary canals. At present, they are not informed about the size of the increased discharge, about the actual discharges through the main canal to the distributary canals, etc. As long as they operate the conveyance and the water distribution themselves, that kind of information can help them to' get a better idea, of what they are doing. For example, they will be able to get more experience in the operation of the parallel gates of the cross-regulators for a certain defined increase of the discharge. This type of information can have a direct effect on better communication between the Resident Engineer Right Bank's .staff and the Irrigation Laborer. Another.way of improving this alerting system is to give exact times of envisaged changes in flow and to limit the changes in the evening.

3.3.3 Upper Pampanga River Integrated Irrigation System (UPRIIS)

The Project Office in Cabanatuan. As' a decentralized system of management, NIA in Manila has given considerable autonomy to its project management. As reported to us by the Head of the Systems Management Division at NIA, the Manager of UPRIIS is considered a Head of a Division at NIA Headquarters. The goal at the highest level of management is to irrigate a certain sized command area given the available water supply. At the Project level, the Project Manager, and his staff, in particular those in the Operations Division and the Water Central Coordinating Center (WCCC) make their decision on the area to be irrigated based on the UPRIIS Operation Rule Curve (Figure 111.12). In the wet season, cultivation is primarily with rainfall from the catchment while diversion from the reservoir becomes significant in the dry season. However, this wet season proved to be not so wet after all. As was apparent at. the UPRIIS Project Office at Cabanatuan, the drought reached crisis proportions on 12 September 1988. The goal at the central and project levels is that once the decision is taken to begin irrigating a fixed area, this is done in consultation with the National Food and Agricultural Council and the Provincial Development Council. The allocation of the available water equitably *among* the districts becomes the concern of the project management, in particular the WCCC.

The progress of the Project is measured by the central authority according to operational data which include service area, program area, planted area, harvested area, cropping .intensity,average yield, and project irrigation efficiency. The next step is Irrigation Service Fee Collection which includes current collectibles, total collection, and Fee Collection Efficiency. It is also monitored on Expenditure - O&M cost per hectare. For this purpose, the project management tracks the following data: reservoir hydrology - elevation of, release from, and inflow into the dam; daily discharge at major flow points [Distributary Canal 1, (DC1) which is significant for the supply to Santo Domingo which is one such point]; daily rainfall by district; weekly status of farming activities by area categorized in the following manner - Area Under Land Soaking, Area Under Land Preparation, Area Under Normal Irrigation Period, Area Under Terminal Drainage, and Area Harvested; and the seasonal monitoring and evaluation of the planted area in each system with reference to the irrigation efficiency. This daily, weekly, and seasonal reporting is supplemented by information communicated at fortnightly meetings convened by the Project Manager with his District Chiefs. On a daily basis as needed, radio and telephone communications exist while field visits are more frequent in crisis situations.

The Water Central Coordination Center (WCCC). The WCCC is one of two key segments of the Project Office that is in systematic communication with the level below. The formal organizational link between the WCCC and the District Office is the WCCC Chief Engineer. He decides upon actual water allocations within the boundaries of the Project and fixes the target flow to be met at key diversion points along the irrigation network.

The Operations Division (actually, Operation and Maintenance) as the second segment, has a different role with respect to the District-level management. If the task of the WCCC is to monitor and evaluate the volume of water present at any given point, this office has as its central task, the monitoring and evaluation of the management that is responsible for ensuring this supply of water. It also has the related task of budgeting for maintenance of the irrigation network. However, due to funding cutbacks over the years, the District Budget does not allow for routine maintenance and what funding is available is not for fixing or replacing gates but for example, for embankment filling and surfacing of the canal. Thus, under the financial budget for 1988, there is an O&M component amounting to approximately ₱1 million in a total budget of approximately ₱6.5 million. This budget is not for system maintenance but, for vehicle maintenance, and transport and travel items. This has implications for the state of the physical system. Under the Irrigation Operations Support Project, operation and maintenance expenditure will be increased to a level of about 90 percent of what is necessary in order to maintain maximum productivity.

The Operations Divisions has the additional task of monitoring and evaluating the performance of the staff at the District level within the criteria monitored by NIA. Essentially, the zone engineer, the hydrologist, the Water Management Technicians, the gatekeepers, and the ditchtenders within a District are evaluated annually and rated under the categories of Operations, Maintenance, Irrigation Service Fee Collection Efficiency, Farmer Organization, and Administration. This evaluation in turn is based primarily on their reporting, and periodically through field visits. It evaluates the targeted estimates; for example in irrigation, this includes the estimated water for **land** soaking at 2.5 liters/ha and normal growth at 1.5 liters/ha. Irrigation efficiency is compiled by taking into account the difference between the area actually irrigated and the projected area at the start of the cultivation season and the targeted and actual discharge of water converted to the percentage difference. Reports are primarily on a weekly or monthly basis and the Water Management Technician's weekly report is a key source of information. In preparing this, he is assisted by the ditchtender. Reports which are essentially progress reports of the cultivation season are submitted to the zone engineer who in turn submits his report to management at the higher levels of the District and Project.

District 1 Office, in Munoz. The District Office is formally under the general supervision of a civil engineer with the title of District Chief. The key personnel for water management at this level are the Operations Engineer and the Hydrologist.

The Operations Engineer is responsible for the overall operation and maintenance functions in the District. The WCCC receives from the district level, particularly from the hydrologist, information necessary to make releases from the Pantabangan Dam at a given time. Hydrologically, at the highest level there is correspondence among the reservoir (project), SDA MC (zone), and the distributary (lateral). At the district organization there is no such correspondence with a hydrological boundary. The irrigated area under the Pantabangan Reservoir covers four Districts. In particular, the WCCC in consultation with the District Hydrologist fixes targets in terms of

(a) flow to be diverted at the Pampanga Diversion Dam (Rizal) through DC1 - a major diversion canal which conveys water. to be shared between Districts 1 and 2 and (b) flow allocated to the respective Districts.

The Hydrologist is responsible for (a) the monitoring of the volume of water allocated to the District. This monitoring comes in the following different forms: maintaining and updating records of rainfall in the command area, and catchment flow; (b) requesting the required supplemental volume of water from the diversion; (c) ensuring that the required volume of water is received at the main supply gate; and (d) requesting a reduction in the amount diverted in response to sudden increases in the available water supply in the District. He is assisted by a' category of officials known as gate-keepers. There are gatekeepers at diversion points, at the main supply gate, and at the head of the Branch Canal. The function of the gatekeeper is to open, regulate, and close the gates (cross-regulators along Distributary Canal 1, particularly Radial Gate 3, the supply gate to the Five Bay Creek and the head gate at Santo Domingo Area). As in the case of the hydrologist, the gatekeepers are also on the payroll of the District - in this case the gatekeeper who must ensure the targeted inflow from DC1 to the supply gate at the Five Bay Creek is really an employee of District 2. Then, from the point of view of maintaining the planned volume of water in the Santo Domingo Area canal, the uppermost effective hydrological boundary is Radial Gate 3 along DC1, while the organizational boundaries are in the realm not of District 1 but of District 2. As mentioned by the hydrologist of District 1, he makes field visits to check the performance of the gatekeeper approximately three times a week and more frequently if necessary. Such performance monitoring is done primarily by visually appraising the water elevation in the canal, especially at Radial Gate 3. There are five points along Distributary Canal 1 at this point with one gatekeeper monitoring approximately two gates. Through staff gauge readings they maintain daily records of water level which are submitted to the hydrologist on a weekly basis. At the point of supply at Five Bay Creek the catchment area is 1,500 ha, but the actual volume of water in the Creek on a given day is computed by taking the difference 'between the supply through the! diversion at DC1 and the flow at Five Bay Creek measured by a Parshall flume. This becomes part of the weekly data submitted by the gatekeeper to the hydrologist of District 1.

Zone 3 in District 1: Santo Domingo Area. The Zone Engineer is responsible for operation and maintenance within this area. He works in consultation with the Water Management Technicians in his zone and the assistance of minor officials also known as gatekeepers, to ensure that the targeted supply of water is received at the Lateral. He keeps daily personal contact with his officials by traveling within his area as well as by meeting them informally at the field station. He is the link between the District and the field levels. The actual impact of the monitoring system on the performance of individual officials begins at 'this level.

The Division. A Water Management Technician is in charge of a division. A different managerial level emerges at the head of the lateral. A Water Management Technician may be responsible for a whole lateral or else (this may depend on the limits of the command area administratively designated under each Water Management Technician) share a lateral with a fellow Water

Management Technician as, for example, in Lateral B. The National Irrigation Administration monitors the performance of these two sets of officials on the basis of their ability to deliver and manage the water estimated for the command area under them. Correlated to this task, NIA also monitors the Water Management Technician's capacity to collect Irrigation Service Fees on the assumption that if the management is able to deliver the water (and water delivery is a prime function of irrigation service), it should also be able to collect service fees from the farmers. For the Water Management Technician for example, the NIA Evaluation allocates 42 percentage points for operations, with 25 for maintenance. Together they make a total of 67 percentage points. If these two aspects in particular are satisfactory, then it is assumed that collections will be satisfactory, and another 25 percentage points are allocated for collections. This is the central operational principle for the NIA and its management at all levels and as one Water Management Technician, quoting the Operations Manager, put it, "irrigation is collection." Procedures for monitoring performance of the managers as well as the channels for communicating information and decisions are all focused on this target. The physical deterioration of the system (the absence of gates, the difficulty of operating the gates) calls for greater ingenuity on the part of the Water Management Technician. Thus, Lateral A, for example, has no gates and to irrigate the command area under it, the gatekeeper has to close the Santo Domingo Area Main Canal. Management at the offtake of the lateral is further complicated by two other factors: the first is the presence of cultivated areas under its command known as, for example, A-S (extra area irrigated beyond the area designed) and the' second, is farmer intervention of the checks along the lateral, established by the agency to ensure equity of supply to the turnouts.

A weekly meeting is held early Monday morning between the farmers and the Water Management Technician to assess the success or failure in meeting farmer demand (perception of the fanners and the corroboration of the ditch-tender are the criteria for' water adequacy at the turnout). The Water Management Technician takes his problems to the Zone Engineer and the other staff at the District Office staff meeting later in the day. Shortfalls in daily supply of water at the lateral are observed but they are approximated on a weekly total basis and reported at the District level. However, in an emergency it is always possible to communicate with the zone engineer during his daily visits to the field station of the Water Management Technicians or during official visits made by the Water Management Technicians who use motor bicycles officially provided. A Water Management Technician is 'assured of a volume of water based on the extent planned for cultivation under the cropping calender. If there is a shortfall he may bring this to the attention of the District management, who in turn may monitor the Water Management Technician to check whether the command area designated for irrigation is in fact cultivated and whether service fees are collected. This weekly deliberation and reports submitted by the Water Management Technician to the zone engineer are aggregated at the district level and submitted to the WCCC for the Irrigation Water Weekly Evaluation. Thus, on 13 September 1988, the evaluation for the last week of August for the Santo Domingo Area was as follows:

Table III.1 Irrigation Water Weekly Evaluation.

Programmed area (ha)	Area soaked (ha)	Area under normal irrigation (ha)	Area under terminal drainage (percent)	Area harvested (percent)
9306.98	9306.98	7668.32	100	72.36

In addition, the Operations Manager of' the Project has fortnightly meetings with the District Chiefs in his Project to evaluate the progress of the cultivation season according to the above criteria and for problem solving.

Preliminary Conclusion: Impact of Organization and Decision Making on Canal Operations

In examining the managerial aspects of canal regulation in the UPRIIS Project, two dominant characteristics emerge: the single interest task specialization focused on water and the decentralized organization with control of the water resource at the UPRIIS Project. These characteristics should logically result in a flexible organization.

At the NIA in Manila, the objectives of management are spelled out as providing irrigation services to the farmers. If the service is satisfactory, the collection of Irrigation Service Fees will increase and hence, Irrigation Efficiency and Irrigation Service Fee Collection Efficiency are its targets for monitoring the Project, and the District. Below the District level these same targets become indices for monitoring the performance of individual managers, notably that of the Water Management Technician and the Zone Engineer. For this purpose, monitoring the total irrigated area and a given volume of water during the four stages of the cultivation season is adequate - these stages are not rigidly time bound and the only constraint is the area originally targeted for cultivation and this is determined by the volume of water available through rainfall in the wet season and the storage in the dam during the dry season. Once land soaking is completed, every attempt is made to complete cultivation of this area by sharing the minimal supply of water available over the entire area cultivated.

As hydrological boundaries cross multiple administrative. boundaries the difficulty of performing this task is increased. It is further compounded by the anomalous position of the district level staff of the WCCC. Thus, while the WCCC at the Project was swift in responding to rainfall, its district level functionaries were less able to do so, given their competing affiliations to Districts. The monitoring functions of the District by the Project is placed in the hands of the WCCC while the control of the staff performing its functions is in the hands of those who are monitored - the District-level staff. Main canal operation and regulation at the SDA are clearly influenced by this procedure. As we witnessed in the case of the hydrologist of District 1 and the gatekeeper of District 2 on whom the former depends to get his water, there are no positive or negative consequences for the gatekeeper, professionally, in responding to the request for water. The hydrologist simply said to the gatekeeper, "you give us our water and do your job." However, as we observed during the rotation under discussion, despite these constraints and taking into account the physical constraints of operation in some laterals, the 'Water Management Technician and the lateral management adapted their operational style to complete irrigation of the command area according t.o schedule.

The lack of a systematic approach to tracking information transmitted at the different levels of the physical and managerial systems and the lack of positive or negative sanctions for effective performance or the absence of it on the part of the managers at these levels is an indication of a lack of awareness of the conveyance function and its impact on delivery and distribution of water in a timely manner. Given the size of the Project and the District, it is the Zone that is meaningful hydrologically and managerially. However. given the distance from the Dam [60 kilometers (km)] and in particular the distance of the last lateral of SDA from the DC1 diversion point, timing of releases to the different offtakes becomes an important factor, particularly at the lateral, and there is at present no mechanism to monitor this conveyance function as performed by the management of the District/WCCC even though it impinges on the performance of the Water Management Technician in particular. Thus, in our observations of one rotation (Annex III.1) while we were clearly aware of the crucial role of radio and personal communications on a daily basis and the role of meetings and reporting on a less frequent basis, we were unaware of the existence of the liaison officer. We subsequently discovered that his role was actually to communicate any changes in releases from the Dam to the gatekeepers along DC1. There was also a lack of complete record keeping associated with changes in the volume of water delivered on any given day. For example, what is verbally transmitted over the radio or the daily targets found in the notebook of the hydrologist were not recorded.

3.4 CONCLUSION

A comparison of the formal organization and the decision-malting processes in the three case studies under consideration from the perspective of their impact, on main canal management reveals the following:

1. Main canal operations in ,its dual aspects of control of issue and regulation of conveyance are influenced by what is identified here as the complexity of organizational design. This complexity is largely determined by the scale of the project and the distance - both spatial and organizational - from the water resource. Scale and distance determine the degree of control that can be .exercised by the management at the main canal as well as at the organizational levels through which it must operate to realize its objectives. From this perspective, the Kirindi Oya Irrigation and Settlement Project is at an advantage over the others.

2. Single- versus multi-agency participation in the organization for, and the decision making with reference to, the water resource. This has the following implication for main canal operations: in the three cases examined,

KOISP and UPRIIS fall into the first category while the Galnewa Project falls into the second. In the first two systems the control of the water resource and its distribution are under the same agency while in Galnewa the control of'the water resource is within the purview of at least three agencies of which one is also responsible for managing the distribution.

3. Single- versus multi-objectives for water by the agency; for example, the priorities established between hydropower and irrigated agriculture. In Galnewa, based on the simulation model for the SOP, it is 100 percent for the first and 90 percent for the second, while a similar choice is made in the Philippines. While the UPRIIS was primarily aimed to conserve water as a dependable year-round supply fox: agriculture, as a multipurpose project, in practice, a trade-off is made between the two dimensions. In Kirindi Oya Irrigation and Settlement Project, water is for agriculture. This prioritizing of water for more than one purpose will not necessarily lead to positive or negative impact on canal operation in itself. Potential complications arise from the give-and-take process between the agencies in their daily operations. For example, in the Galnewa case, in 1986/87, the lower priority for irrigated agriculture was accompanied by an unsystematic issue with reference to timing of such issues. This is the result of unplanned shifting of priorities influencing the established operational targets for water.

4. If priorities are shifted, or even otherwise, for example, any change in the anticipated inflow into storage must be notified to the affected partners so that they can adjust their targets accordingly. The fewer number of levels (partners) of the organization which act as decision centers above the significant storage (for example, at Galnewa, Kalawewa Reservoir), as well as below, through whom such information must be accessed are factors in the timely operations of a main canal.

5. The presence of many decision centers may be mitigated by the presence of fewer decision makers at each center. Thus, the fewer the number of decision makers through whom information must be accessed at each level, the better it is as an organization for canal operations. This has two implications: first, decision making regarding water resources is not fragmented among a number of positions and as a result, the lines of communication are unambiguous. Second, responsibility and accountability can also be clearly demarcated.

6. The number of tasks that must be performed by personnel managing water over and above this particular task has an impact on the amount of time and care expended upon the task of main canal operations. The UPRIIS has a single task while Galnewa is multiple-task oriented. The Kirindi Oya Irrigation and Settlement Project illustrates the situation where the concern over construction has consequences for the concerns of irrigation. Following this, is the tendency of personnel to concentrate on those tasks emphasized by the agency at the expense of others.

These six factors may individually or in multiple combinations assist or impede the success of canal operations. They determine and limit the options for decision making in a systematic and timely manner. The fit or lack of

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fit between layout and the organization for management further influences canal operations. Any negative consequences from the above can be mitigated by the presence of the following additional factors:

7. A decentralized organization in contrast to a centralized one. Through decentralizing the management, power and authority for decision making will be disbursed to multiple levels in the organization while a centralized organization concentrates this at the top of the hierarchy. This gives the discretionary power of decision making to managers who function under uncertain conditions (shifting of priorities) to have some alternative options to counter unanticipated change, at the operational level, without waiting for clearance from above. In the UPRIIS, the levels of organization and corresponding decision making are thus decoupled at the Project and secondarily at the District. However, as discussed elsewhere (Chapter IV) the decoupling of the physical system can to a large extent facilitate canal operations within a centralized organization such as Galnewa.

8. A reliable and predictable management information system for accessing information will enable timely response on the part of management at different levels. In addition to regular reporting, and meetings routinely aimed at better informed decision making, the telephone and the radio will enable the management to be in control of the exceptional. However, to be effective, information received at each level and through each mode must be part of one integrated management information system. In the absence of this, the efficacy of the system, exceptional at one level (WCCC in the UPRIIS and the System H Water Panel in Galnewa) may be less effective at another level (the District in the first case and the Left Bank in the second). In the KOISP, in the absence of such formal mechanisms, the Senior Irrigation Engineer collects his information on his own reconnaissance. The absence of this will result in ad hoc decision making.

9. The fit between objectives as specified in the operational plan of the management, for example, during a cultivation season, and its criteria for monitoring its employees will determine the efficiency with which the agency can perform the dual tasks for canal operation. A disjuncture between the objectives specified in the operational plan which map be for example, supply-oriented, and the actual operations which may be demand-based, and the monitoring of staff performance according to the original supply target will create ambiguities and uncertainties for the management. In any event, post hoc evaluation of the cultivation plan based on area cultivated and yields (and this is not an operational plan) while construed as an evaluation of the employees collectively, falls short of identifying individuals, allocating responsibility, and monitoring their performance. leading to rewards and sanctions. Main canal operations must ultimately rest on this performance of individuals.

10. The importance of training of management for canal operations cannot be underestimated. The actual physical operation of the canals is commonly in the hands of an individual who is known as irrigation laborer or a gatekeeper. His understanding regarding Canal operation is the result of an adaptive response determined by the necessity to mediate between farmer demand and the water supply available, one or both of which are often

erratic. Typically, these individuals are recruited without any experience or training, and allowed to acquire know-how for operations with time and on a trial-and-error' basis. This may not be always optimal. In addition to technical training, training ,in the cognitive and affective domains is recommended not simply for operators at this level, but at all levels of management. Thus, the advantages derived from the management information system, the operational plan, and the monitoring will ultimately rest upon the awareness, the motivation, and incentive of management to implement .objectives for canal operations and this can be achieved in large measure through training going beyond the standard technical training.

CHAPTER IV

IMPACT OF PLANNING AND DESIGN CHARACTERISTICS ON THE MANAGEABILITY OF IRRIGATION SYSTEMS

4.1 INTRODUCTION

Each of the main canals 'studied is an integral part of a larger irrigation system. In Chapter II, the structure and layout of the whole physical system, and its natural decomposition into subsystems on the basis of their water sources have been examined. It was also pointed out that one of the important elements to be considered was the nature of the link between the subsystem studied and the next higher system level. This will determine the degree of freedom (or autonomy, within certain limits) available for operations at the head of the canal studied with respect to the water resource without interfering with, or being affected by, the operations of the higher-order system; the conveyance system.

Intermediate storage was highlighted as a useful means of decouplinr complex hydraulic systems into simpler subsystems, thereby relaxing the link of dependency between the conveyance system upstream of the storage and the distribution subsystem below the storage. The subsystem is thus provided with some flexibility for the control of flow at its head, .as in the case of the Kalankuttiya Branch Canal. Regulation of the overall system is also facilitated.

It was also pointed out that hydraulic "controls" like duckbill weirs used for controlling canal water level were able to serve a similar purpose, easing the dependency link between the flow at an offtake (or the head of a subsystem) and the variations of flow resulting from operations in the parent canal (or the conveyance system). Hydraulic "controls," though restricting the flexibility with respect to the operation of the conveyance system, when compared to gated cross-regulators, are nevertheless able to provide opportunities for the control of flow at the offtakes nearby.

In Chapter III, the organization design and the processes of decision making that are central to the management of the main system in three different projects representing three different physical configurations are examined. This was done by reviewing, in a series of three case studies, the formal organization, the decision making taking place at each administrative-managerial level, the communication of information from one level to the next one, dorm to and including the level of the operators- often referred to as the executing part, but who appear actually to be key decision makers - and the role of feedback at the various decision-making levels involved in the operations of the canals.

In Chapters II and III, the lead idea concerns the amount of centralization versus decentralization which exists in both the physical system, regarding the water resource storage, and the organizational system regarding the decision making related to the mobilization of that resource.

For example, National Irrigation Administration/Upper Pampanga River Integrated Irrigation System (NIA/UPRIIS) which appears to have a rather decentralized managerial structure is responsible for operations of an extensive main system of major diversion canals from a central water resource stored in the Pantabangan Reservoir. On the other hand, Mahaweli Economic Agency/System H is well known for it centralized management though the physical system displays a great deal of dispersed storage capacities.

In this chapter, the manageability of systems is analyzed from the point of view of the availability of conditions necessary for the management of the two basic functions of main canals: the delivery function and the conveyance functiun,

The management of the delivery function means the control of water issues, assuming adequate water supply at the head of each place of delivery. In the first part of this chapter we examine whether the conditions to exert control over the water issues are available to an operator or not. These conditions include either physical facilities like gates or measuring devices - their availability depending on the design.,construction, and maintenance processes - or managerial output such as distribution targets - made available as a result of the water allocation decision-making process usually performed at the highest level of an agency by arbitration between water demand and water resource, but also at the level of the operators themselves who often tend to meet the demands of neighboring farmers.

The three criteria used to assess the manageability of the system in respect of the control of water issues are as follow:

Criterion A: Availability of operational delivery targets.
Criterion B: Availability of reliable informatipn on water flows.
Criterion C: Availability of means to influence the water issues.

The assessment has been done at the head (main canals) of each subsystem studied and at the offtakes along those canals. The same criteria are used for the head and the offtakes, but it is important to examine the conditions at these two locations, separately. This is because the two types of locations may differ greatly in the physical facilities provided by the design and the managerial level to which the operators are reporting, as well as in respect of the hydraulic conditions existing at these locations. It should be noted, however, that existing hydraulic conditions are viewed in this study as an external factor and not as an intrinsic element to be considered in assessing the manageability of the system from the point of view of the delivery function.

The hydraulic conditions (water level in a tank or a canal) prevailing at the head of a delivery point are important, especially the variability of these conditions, because then, additional operations would normally be required to achieve similar performance in the control of water issues.

The management of the conveyance function means the regulation of the transfer of water throughout, a system (including main canals) to provide adequate water supply at the various delivery points required for the above-mentioned three controls of water issues. The availability of specific conditions for doing this is (briefly reviewed in the second part of this chapter.

As a preliminary remark, our observatiohs reveal that the need for managing the transport of water throughout main canals and the requirements for achieving this are usually not well perceived by agencies, and less by the operators. This is perhaps exemplified by the statement attributed to a Sri Lankan engineer in Chambers (1988): "You open the sluice, and you go to sleep." On the other hand, the advantage of controlling the water issues at the offtakes and the requirements for doing so are better known. The tendency, however, is to emphasize the 'means to ensure the control of the delivery function (i.e., flexible gate arrangements, improved measuring devices, multiplication of the points of monitoring, and centralization of the results,. etc.) neglecting the means and requirements for regulating the conveyance function.

Because canal regulation applies to the canal system as a whole, it is an operational task that should be managed at a level of decision making within the agency capable of overseeing the whole system; Individual operators might be in a position to manage the control of water issues well, provided there are appropriate means at a particular location. But, one cannot expect. the operators to manage the conveyance of water with the localized information they have on the system.

There is a common belief, however, that canal regulation might eventually result from the addition of independent operators controlling the water issues at the various offtakes. This should be associated with another belief that flows in main canals are largely invariant with time (steady **flow** regime). This, the steady flow regime, an ideal situation, would eliminate the problems of managing the conveyance of water. Such an assumption is often considered in the design of main canals and agencies tend towards achieving the distribution of water under **such** conditions. But field observations[1] in the various canals studied show that this ideal condition is seldom achieved.

In this chapter, a number of examples will be given to illustrate the different reasons for the variability of flows in main canals. Some, like changing the water issues at the headworks in response to rainfall, are

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[1]The longest continuous period of stable flow recorded in the Santo Domingo Area (SDA) Main Canal at the level of Lateral B was no more than 4 days (from 19 August to 23 August 1988) for the whole period of observation.. Stable flows prevailed for 6 days in Kirindi Oya Right Bank Main Canal (from 29 April to 5 May 1988) but this corresponds to a period for which the system was artificially maintained steady for the purpose of calibrating a mathematical model (no gate interventions of any sort were permitted). At Rajangana Left Bank Main Canal, an exceptionally long period of stable and high flows was observed near the end of the cultivation season in July to August 1988, but this was reportedly an attempt by the agency to drain off the reservoir for repairs at the main sluice.

intentional. There are other reasons which are unavoidable in any attempt to manage the system. For example, the adjustment of flow at the major offtakes or, more significantly, the operations of gated cross-regulators induce variations of flow in.the main canal which themselves prompt other maneuvers. This closed-loop situation might sometimes result in permanent unsteady flow conditions as observed in the Kirindi Oya Right Bank Main Canal near Branch Canal 2 (Figure IV.1).

Thus, managing the conveyance of volumes of water through the main system from tank to tank, or from canal reach to canal reach in a dynamic mode is the essence of canal regulation. . It is also a challenge to irrigation agencies if any control of the primary distribution of water within extensive irrigation systems is to be achieved.

Three specific criteria have been used in this study to evaluate the manageability of the systems with respect to the regulation of the conveyance of water. They are as follows:

Criterion D: Availability of operational targets for the conveyance of water.

Criterion E: Availability of means to store and release water within the main system and to control water level at key locations along the main canal.

Criterion F: Availability of information regarding the status of water storage (or water Level) in reservoirs (or main canals).

Criterion G: Availability of means for communicating the information required for the regulation of the water transfers.

4.2 CONTROL OF DELIVERY FUNCTION

The three criteria used to assess the manageability of the system in respect of control of water issues are discussed below.

Criterion A: Availability of operational delivery targets. The availability of operational targets is a prerequisite for any control process. Delivery targets might take the operational form of water depth corresponding to a discharge at the calibrated gauge of an offtake. The study will assess:

* whether there are delivery targets formulated explicitly at some level within the system, either at the head of main canals or at the offtakes;
* whether the targets of the agency are known to the operators or whether they use their own, based on, for instance, farmer demand with or without communication of these latter targets to the agency;
* whether the agency targets are standing orders or whether they are regularly updated.

Some of the constraints and difficulties related to lack of communication of information pertaining to operational targets between the operators and other operational levels within the agency will be highlighted.

Criterion B: Availability of reliable information on water flows. The availability of reliable information on water flows is also a condition for the operators and other decision makers to get feedback. Appropriate feedback is important from the point of view of the control of water issues as well as for the overall canal regulation. The study will examine whether and how an operator has the possibility to know if the delivery targets are being met or not at a given time. In particular:

* what facilities are provided by the design for the assessment of flows in the main canal and at the offtakes, and whether these devices are reliable;

* what constraints have to be faced in assessing flows in canals under field conditions (e.g., submergence, siltation, rating curves, etc.).

Criterion C: Availability of means to influence the water issues. The availability of means by which an operator can influence water issues is an important element towards achieving control of water issues. But it is also important to note that such maneuvers transform gatekeepers into decision makers. Wherever operational flexibility exists it is important to evaluate how the operators cope with it and manage it. The study will attempt to respond to the following:

* what is the range of operational options made available to an operator given the operational flexibility provided in the design of the canals studied?

* what are the other important constraints that determine the gate-keeper's decision to operate the system (the "what" and the "how")? For example, the gate could be damaged, or the design of the gate could be such that the gatekeeper has to undergo considerable hardship/discomfort to operate the gate to achieve a particular setting time-effectively.

* is there any advantage for the operators in having estra operational flexibility, given the complexity of management which it implies?

A summary of the evaluation of the manageability of the different canals on the basis of these criteria is indicated in Tables IV.1 and IV.2.

4.2.1 Control of Water Issues at the Head of the Subsystems Studied

Kirindi Oya Right Bank Main Canal

Delivery targets. The Senior Irrigation Engineer, Water Management Division decides upon the daily hater issues to be delivered at the right bank main canal headworks (Criterion A). In doing this, the Senior Irrigation Engineer refers to the seasonal irrigation schedule he had

Table IV.1 Control of water issues at the head of sub-systems

CRITERIA	KALANKUTTIYA BRANCH CANAL Tank Sluice	SANTO DOMINGO AREA SDA-NC Head Gate	KIRINDI OYA RIGHT BANK MAIN CANAL Head Gate	RAJANGANA PILOT CANAL* Head Gate
A. AVAILABILITY OF OPERATIONAL TARGETS (for the water issue)	yes and explicit	yes but not explicit	yes and explicit	yes, explicit and openess max.
- Formulated by whom? and when?	y the IE at each rotation.	WCCC on request of Hydrologist of listrict I,	Seasonal Operation Plan by SIE at the onset of the season	Set by ID-TA, but not conform to initial plan, and not similar to the Control canal.
- Are they explicit? and known?	'arget explicit and recorded n the block office.	'arget assumes local flow but no leasure, no record of SDA target	Explicit, well known and recorded	Target are given openless maximum
- Are they revised? how?	'evised frequently on request f the Unit Manager and during be rain.	Revised on request of Hydrologist and for rain. Gd communication, contact radio permanent with WCCC	Revised on request of RE-RB and when it rains at Lunuganvehera.	Target hardly revised for the whole season.
B. AVAILABILITY OF RELIABLE INFORMATION ON WATER FLOWS	good at MSI but not at the tank sluice)	poor actually limited to SDA Suppl.8G)	good	good (but recently installed in 1987)
- Meas.device physically fit	Good, recorder of the MEA/Flow Monitoring Unit operational	Parshall Flume available and constructed as per design	Yes (main sluice itself)	Fair, baffle distributor used in conjunction with an automatic gate but gate already unbalanced.
- Meas.device hydraulically fit	Yes, good measurement station	Often submerged	Yes	Needed additional head in the main
- Calibration/Sensitivity/Accuracy	Adequate calibration and well maintained by MEA/FMU	Not calibrated, flow overestimate by 40 % with MIA-Measur. Tables	Fairly well calibrated by the ID, through the orifice formula and using water tank level.	Good, pre-calibrated accuracy +/- 10 %
C. AVAILABILITY OF MEANS TO INFLUENCE THE WATER ISSUES	critical (3 gates damaged)	not direct & unconvenient only at Supply Head gate on DC#1)	Simple and effective	Simple and effective
- Flexibility and variety of means	Potential almost totally eroded by disrepair	Potential flexibility but useless	Only one electrical operated sluice	Only a set of calibrated shutters to be open or closed fully
- Convenience for the operator	medium, leak could not be sealed in Yala 1988	no operations at all at SDA headgate	Very convenient	Very convenient, no adjustment, direct reading of flow delivered by steps of 10 l/s
QUALITY OF THE CONTROL OF LEVEL UPSTREAM (Performance of the conveyance)	Fair (tank regulation)	Poor (ineffective regulation of DC#1)	Good (reservoir regulation)	Automatic (automatic control)
- control of level u/s the head	Tank level was maintained within operational range of level throughout Yala 1988	Levels are not controlled at the head of SDA head gate and poorly at Supply Headgate in DC#1	Little and slow variation of level in the reservoir.	Automatic downstream level control irrespective of level variations in the main canal.
need/for frequent gate resetting	One or two daily adjustments, but only 10 % of the total operations are for restoring targets.	No operations performed at the SDA gate	No adjustment required when tank is at nominal level.	No adjustment required at the baffle distributor.
MANAGEABILITY (overall rating)	Fair	Poor	Good	Good

* Rajangana Pilot Canal is actually a Distributory Canal

Table IV.2 Control of water issues from the main canal

CRITERIA	KALANKUTTIYA Offtake from Branch Canal	SANTO DOMINGO AREA Offtake from SDA Main Canal	KIRINDI OYA RIGHT BANK MAIN CANAL Offtake from Right Bank Main Canal	RAJANGANA PILOT CANAL* Offtake from D-Canal
A. AVAILABILITY OF OPERATIONAL TARGETS (for the water issues)	yes, explicit at the start (unclear near the end)	No quantitative target (but proportional division target)	unclear and no update	yes, explicit and openess max. (but for 66 % of F-Canals only)
- Formulated by whom? and when? - Are they explicit? and known? - Are they revised? how?	Supply target communicated by IE to the ILs, Explicit at the start of the rotation; But override by demand based target toward end of rotation	Operation plan worked out by Zone Engineer and WMTs: contin./rotati. No real supply target; No constant level target in MC. gate keeper has its own level reference but not explicit.	Worked out by IE-RB on basis of the Seasonal Operation Plan of SIE Delivery target not explicit, Level target in MC explicit (FSD) but accommodated by operators Demand based targets prevailing	Set by IL on order of TA, but definition of target unclear Explicit (as per shutter opening), openess max. for 6 FCs out of 9 Updating of target unclear.
B. AVAILABILITY OF RELIABLE INFORMATION ON WATER FLOWS	Partial only Fair(25%); unreliable(40%)	Limited (not reliable, over-estimated)	Limited (often over-estimated)	Fair (but for 66 % of F-Canals only)
- Meas.device physically fit? - Meas.device hydraulically fit? - Calibration/Sensitivity/Accuracy	Yes (85 %) Yes (30 %), weir box occasionally submerged Calibrated; Accuracy medium	Parshall Flumes available at major Laterals Not fit, submergence prevalent at most locations NIA-Water Measurement Tables improper, no calibration.	No; half of the weir boxes are damaged in upper reaches No; frequent submergence of the weir boxes No calibration, but use of weir equation often improper.	fit: all 9 "modules" fit: only 6 "modules"; level control at the head altered for 3 No calibration needed while functioning at nominal condition.
C. AVAILABILITY OF MEANS TO INFLUENCE THE WATER ISSUES	Limited to a minimum but effective	Important potential but eroded by disrepair	Important potential for complex operations	Limited but effective
- Flexibility and variety of means - Convenience for the operator	Minimum means (limited to the gate at each offtake, no Cross.Reg. but 1) Simple, all gates have been maintained in working conditions since commissioning.	Maximum flexibility but potential currently limited to the manoeuvre of gated regulators at the Lateral and "checks" at the minor offtakes CR in critical conditions, only one operation per day in general "Checks" operations inconvenient.	Maximum flexibility Complex and cumbersome to operate, (1 to 6 gates to adjust/diversion) but operators tend to simplify and concentrate on the operation of cross-regulators and less at offtakes.	Minimum Simple, opening and closing of shutter no adjustment required besides setting the target
QUALITY OF THE CONTROL OF LEVEL UPSTREAM (Performance of the conveyance)	Fair at the duck-bill weirs (hydraulic control)	Irrelevant	Feeble (manual control)	Good but partial (hydraulic control)
- control of level in the main canal at the offtakes - need for frequent gate resetting	Fair for 65 % of the offtakes located closed by the DBW. Limited during water issues (Mean: 1 operation per 2 days during water issues and 1/day between issues)	Level/flow control is not the relevant objective but flow division. Limited (Mean: 1 operation per 2 days)	Achievement limited Need for frequent adjustment of the cross-regulator (up to 8/day) level variation unpredictable at the tail; night operation required	Control by weir effective, except for the altered tail weir. No resetting needed
MANAGEABILITY (overall rating)	Fair at some offtakes	Irrelevant(1)	Poor	

* Rajangana Pilot Canal is actually a Distributory Canal

(1) The manageability in terms of control of the flow (discharge) issued at the Lateral has been considered irrelevant but the system was found managed reasonably well with "degraded" objective i.e sharing equitably whatever quantity of water came in.

elaborated at the start of the season. In the case of lowland paddy (the crop grown during the study period) the schedule is based on the following water requirements:

Table IV.3. Kirindi Oya Right Bank Main Canal: Data used by the Irrigation Department to compute irrigation water requirements.

	Stage number	Week number	Requirement (l/s/ha)[a]	Coefficient
Land preparation and establishment	1	1 - 4	1.70	1.1[b]
Vegetative	2	5 - 7	1.30	0.8
Flowering and yield formation	3	9 - 16	1.60	1.0
Latter part of yield Formation and ripening	4	17	1.10	0.7
	5	18	0.25	0.2

[a]Liters per second per hectare.
[b]Sometimes increased to 1.2, depending on the progress of land preparation.
Source: Senior Irrigation Engineer's Office, Kirindi Oya.

The water requirement during Stage 3 (weeks 9-16) is chosen as a standard (Coefficient 1) and the computations of water requirements are performed for this period. The water requirements for the other periods are derived by applying the coefficient corresponding to the period in question.

The different stages applicable during the study period are indicated in the cultivation calendar of the right bank main canal system between December 1987 and July 1988 (Figure IV.2).

For the convenience of comparing theoretical and actual main canal water issues, a weekly weighted average discharge (WWAD) rate was computed, based upon the Irrigation Department's (ID) planned weekly irrigation schedule for each canal taking off from the right bank main canal as follows:

$$WWAD = \frac{\text{Summation [Discharge (m}^3\text{/sec) * Duration of flow during week (days)]}}{7 \text{ (days)}}$$

The weekly weighted average discharge rate was assumed to prevail in a given canal over the seven days of a particular week and to represent the water requirement of that canal. The requirement of each tract was obtained by aggregating the daily requirements thus obtained for the different canals in the tract. The theoretical ex-sluice requirement was then computed by adding the requirements of the 'different tracts (conveyance and operational losses in the main canal have not been taken into account). the appropriate coefficient being applied depending on the stage of growth of the crop in each tract. For example these rates., if all three tracts are in Stage 3 (coefficient 1), would be:

Tract	Command area (ha)	WWAD rate (m^3/sec)
1	748	1.58
2	891	1.95
5	990	2.17
Total	2629	5.70

Actual water issues. Figure IV.3 shows that the actual daily discharges at the main sluice (as recorded by the Irrigation Department) generally exceed the theoretical weekly weighted average discharge values. This difference could be assumed to cater to the right bank main canal operational and conveyance losses (the Department's weekly schedule already accounts for losses in field channels and distributary canals). A very rough estimate of main canal losses could be obtained by comparing the oversupply to the theoretical ex-sluice weekly weighted average discharge requirements as shown in Figure IV.4. (Estimates for the period of canal closure in April are indeterminate.) In general, the oversupply appears to be less than 35 percent, which is the value assumed for losses in unlined main canals in the Irrigation Department Technical 'Note 6.

The most substantial discrepancy between theoretical weekly weighted average discharge requirements and actual discharges was observed for the period 10 April to 10 May 1988. The rain at Lunugamwehera (103 millimeters [mm] from 9 to 14 April) prompted the closure of the main canal for five days, between 12 and 16 April, according to the standard procedure. Irrigation issues resumed on 17 April at the flow rate of 1.96 oubic meters per second (m^3/sec) 1.175 cusecs) which is nearly equal to the flow of 5.24 m^3/sec (185 cusecs) that prevailed before the rain. The issue was maintained at 4.96 m^3/sec until the end of April owing to the last date for the completion of irrigation .in Tract 2 being extended beyond the initially planned date of 19 April. There! did not appear to be a recomputation of the target for this prolongation of the irrigation issue in Tract 2. The information available to the senior irrigation eneineer to determine the magnitude of the water issues needed after canal closure due to the rain are not clear. During the three-week period which followed the closure of the canal in April, it was observed that the discharge was nearly two and a half times that of the weekly weighted average discharge rate corresponding to the initial schedule.

The standard procedure to respond to the rain is to close the main canal for five days if rainfall exceeds 75 mm (3 inches) at Lunugamwehera. The rationale behind this is that the nest two days could be allowed for canal refillinn and the normal water issues could then recommence after seven days (the normal rotational period). The spatial distributipn of rain in the area, however, is uneven. This is clearly demonstrated by the fact that on 27 and 28 April there were 113 mm of rain at Wirawila but only 6 mm at Lunugamwehera. See also Table IV.4 and Figure IV.5. At present there does not appear to be a plan for reducing the issue of water at the main sluice in such a case. It was reported from the field that there had been excess water on 27 and 28 April at the tail of the rinht bank main canal.

Target flows in the instruction form of the senior irrigation engineer are clearly known and recorded. He sets the daily target flow to be issued at the right. bank main canal main gate and makes sure that. it is correctly implemented. He also eets some feedback from the field through regular inspection along the main canal to ascertain whether the issues are adequate with a view to preventing oversupply.

Means for operations. The senior irrigation engineer communicates the required flow to the Resident Engineer (Headworks) who can then calculate the corresponding opening of the radial gate installed at the head of the right bank main canal. The senior irrigation engineer often computes the opening of the radial gate corresponding to the required flow himself. using the equation that relates the discharge through the gate to the gate opening and the reservoir water level. The equation has apparently been calibrated against field measurements by the project staff. It was observed once during the season that, in the absence of a chart or a precomputed table to help in this process, the computation of gate opening is not entirely error-free. This process, however, has now been systematized through the use of computer spread-sheet software.

Each operation is executed by an irrigation laborer. He is supervised by a technical assistant who in turn is instructed by the Resident Engineer (Headworks). The headgate is electrically powered but there is a manual backup in case of power outage.

Information on water flows. A meter permits to adjust the opening of the gate as per the target value. Although the scale of this meter does not. allow fine tuning of the gate adjustment, researchers of the International Irrination Management Institute (IIMI) have found it to be able to provide reasonably accurate flow control - in the course of a field measurement campaign carried out for the calibration of a mathematical flow simulation model of the Kirindi Oya Right Bank Main Canal, a discharre increment of 1.552 m^3/sec was measured' in the main canal when the required increase in main sluice discharge was 1.5 m^3/sec, a difference of only three percent.

Variability of water level. The daily variation of the water level in the Lunugamwehera Reservoir is limited owing to its large storage capacity-. This favorable design feature makes it possible to maintain water issues at the headworks fairly constant and as per target without frequent intervention to reset the main sluice gate opening.

Preliminary conclusions. The manageability of the system, with respect to the control of water issues released from Lunugamwehera Reservoir into the Kirindi Oya Right Bank Main Canal, appears to be satisfactory. Explicit water-issue targets at the headworks are formulated and communicated to the staff in charge. Instructions at this level are strictly executed to achieve the intended result.

Although the capacity to control target discharges at the head of the system appears to be adequate, the overall performance of the system would also be determined by the decision-making process related to the definition and continuous updating of the targets, expressed in terms of water to be released at the head of the right bank main canal and conveyed through the different reaches of the canal.

In other words, the water-allocation process appears critical and might' need improvement, in order to provide more pertinent objectives for the conveyance of water; a notion which is lacking at present. This point will be further discussed in Section 4.3 of this study.

Kalankuttiya Branch Canal

Delivery targets. Since the creation of the Main Canal Unit to oversee operations in the Left Bank Main Canal of Kalawewa Reservoir in early 1988, the operation of the Kalankuttiya Tank came under the responsibility of this Unit. The Engineering Assistant heading the Unit is supposed to decide upon the targets and the issues to be delivered from the Kalankuttiya Tank to the branch canal in compliance with the water-allocation decisions made at the project level by the System H Water Management Panel.

According to the new (since 1988) organization of operational responsibilities (Figure IV.6), the Engineering Assistant should receive the schedules worked out by the Irrigation Engineer, Galnewa, who is in charge of the upper section of the branch canal, and the Irrigation Engineer, Meegalewa, who is in charge of the lower section of the branch canal. The Engineering Assistant would cross-check the total requirements received for the Kalawewa Left Bank Main Canal against the allocations, make any alteration as required and determine the operations to be carried out at the main sluices of the three reservoirs (Kalawewa, Mulannatuwa, and Kalankuttiya) as well as the distributary canals taking off the left bank main canal to serve the Galnewa irrigation block.

But very little of this plan was actually implemented during <u>yala</u> (dry season) 1988 and most of the important operational decisions regarding Kalankuttiya such as opening and closing of the tank sluice, altering delivery schedules, etc., were continued to be taken by the Irrigation Engineer, Galnewa, who exercised these same responsibilities in his previous capacity as Irrigation Engineer of the now defunct Kalankuttiya administrative block.

Thus, the Irrigation Engineer, Galnewa, effectively decides on the issues to be delivered from the Kalankuttiya main sluice (Criterion A). He was assisted by a new Engineering Assistant, Galnewa, posted at the

Kalankuttiya Community Training Center, who gave instructions to an irrigation laborer performing the maneuvers at the tank sluice, as well as setting daily the distributary canal gates in Blocks 305 and 308 under the Galnewa administrative block. It was reported that the Irrigation Engineer, Galnewa, had complained of the difficulties he experienced in deciding the daily releases from the Kalankuttiya Tank because he lacked the means of communicating with the Meegalewa administrative block, especially after the transfer of their engineering assistant who had initially prepared the irrigation schedule for the lower section of the branch canal.

As a result of this situation, it seems that very little control has been exerted during yala 1988 regarding the issues from the Kalankuttiya Tank with respect to the water allocation objectives and targets decided at the System H Water Management Coordinating Panel. The Panel itself did not meet as frequently as it did during the previous season. This was partly owing to the relative abundance of water in Kalawewa during the present season which apparently reduced the need for effective management of the available resources. Another contributory factor was the prolonged absence of the Deputy Resident Project Manager (Water Management), owing to his hospitalization, who used to chair the panel meetings.

Assessment of water flows. For assessing the flow issued into the branch canal, the laborer who operates the main sluice uses as a reference a calibrated staff gauge (denoted MS1) located about 200 meters downstream of the headworks (Figure IV.6). The measuring station is fitted with a stage recorder that was installed to serve the needs of the Flow Monitoring Unit, but not explicitly for the operations of the branch canal although the Irrigation Engineer's staff make use of the calibration table developed and maintained by the Flow Monitoring Unit to assess the branch canal flow. The operations staff of the block office, however, do not use the records which are available at the Unit to get feedback on the canal operations performed.

Furthermore, the flow assessed at this station does not always represent the flow issued at the Kalankuttiya Tank. This is because water is sometimes diverted into two distributary canals, 305-Dl and 308-D1, located in-between the tank and the staff gauge MS1. Estimating the flow diverted into these canals is either unreliable because of the submergence of the measuring weir (305-D1), or not possible because of the absence of any functioning measuring device (308-D1), which had been destroyed by the farmers.

Therefore, assessing the flow released from the tank at times when 305-D1 and 308-Dl are receiving water is guesswork. For all practical purposes, the assessment of water issues to the branch canal is done at the MS1 location by means of the calibrated staff gauge of the Flow Monitoring Unit (Criterion B). It has sometimes been the practice to supply the two distributary canals at the head of the system separately. Interference with water issues to the rest of the branch canal is thereby limited and adjustment of the main gate, which would be otherwise more complex, is facilitated.

Means to influence water flows. Another point that should be highlighted is in regard to the physical condition of the headworks

(Criterion C). There are three gates at the headworks but only one is functioning. Furthermore, throughout the season, there was a continuous leak of about **280-340** liters per second (liters/sec) **(10-12** cusecs) through these gates. Between rotations, water was kept standing at a high level in the head portion of the branch canal by closing a gated cross-regulator located about **150** meters **from** the main sluice, apparently in an attempt to reduce the flow of the leak. During the previous season (maha, wet season, **1987-88),** the irrigation schedule was so arranged as to utilize the leak to supply water to the two distributary canals at the head of the system **(305-D1** and **308-D1).** But during the season under consideration (yala **1988)** no such intention was apparent - all 20 distributary canals taking off from the branch canal were supplied simultaneously for most of the season. Furthermore, in mid-August during this season, the last working gate malfunctioned and could not be operated any more. This period, between **19-25** August **1988,** is visible in Figure IV.7 which represents the record of tank water levels, main sluice gate openings, and average daily discharge in Kalankuttiya branch canal. The agency was obliged to repair one of the other two gates but the gate remained difficult to operate.

Actual water issues compared to the initial schedule. Water issues in the Kalankuttiya Branch Canal started on **8 May 1988** although the first issue had been originally planned for **10** May. Under the original schedule, drawn up by the Irrigation Engineer, Galnewa, in coordination with the Engineering Assistant, Meegalewa, it had also been decided to issue water continuously for land preparation and planting till 16 May and to commence issues on a rotational basis from 23 May. The period of water issue for land preparation (for the whole system), however, was extended till **19** May **1988.** A special issue was thereafter made to the tail-end distributary canals (in Meegalewa administrative block) on 20 May in response to a request of the Engineering Assistant, Meegalewa. There have subsequently been **13** rotations until the branch canal was finally closed on 26 September **1988.** The actual schedule and durations of issues (from three to four days) was generally decided upon with very short notice and with due consideration to the rainfall which has been particularly abundant during yala **1988.**

Figure IV.8 indicates the actual and initially planned water issues in Kalankuttiya Branch Canal during yala **1988.** The discrepancy (both in terms of volume and timing) between the initial plan drawn up at the beginning of the season and the actual operations is clearly shown in this figure. These differences are notably owing to rainfall. The agency should thus have the capacity to update and successfully implement their targets in accordance with the hydrological conditions.

The daily rainfall contribution to the water deliveries is highlighted in Figure **IV.9** which compares the planned and actual daily water deliveries per unit area at the staff gauge **MS1** (in terms of equivalent depth of water).

Main sluice interventions. The start, end, and duration of each rotational issue, and the number of adjustments performed at the main sluice during each rotation are indicated in Table IV.5. This table has been established from the agency's **record** of water levels at the staff gauge **MS1,** supplemented by IIMI's **own** field observations.

The period at the beginning of the yala cultivation season, 8-14 May 1988, will be used as an example to illustrate the current iterative mode of adjustment of the main sluice of the Kalankuttiya Tank and the difficulties involved in adjusting the flow to meet a given target. Table **IV.6** and Figure IV.10 represent the hourly values of water levels recorded at the calibrated staff gauge MS1 and the corresponding values of discharge for the above period.

The target initially set for the first irrigation issue on 10 May was **1.6 m^3/sec** (57 cusecs) which is equivalent to a height of 1.1 meters (3.6 ft) at the calibrated staff gauge MS1. The start of the season, however, had been advanced to 8 Map with water being issued to some of the head-end distributary canals, and this target value had been already attained the previous day (9 May) by an operation at the main sluice performed at 2300 h on 8 May. In addition, there appears to have been further interventions at the main sluice between 0900 h and 1200 h on 9 May. The initial target of 1.6 m^3/sec for 10 May was increased to 2.0 m^3/sec (71 cusecs) (i.e., 1.19 meters, or 3.9 feet [ft], at the staff gauge MS1) by the Engineering Assistant, Galnewa, in response to a request of the Engineering Assistant, Meegalewa, to facilitate issues to the tail-end distributary canals. The new target was not achieved at once. A first opening of the main sluice was done at 1200 h on 10 May which brought the level at MS1 to 1.3 meters (4.25 ft), equivalent to 2.38 m^3/sec (84 cusecs). It was followed the next day (11 May) by four alternate closures and openings of the main sluice that resulted in a water level of 1.22 meters (4.0 ft) at MS1 (i.e., 2.1 m^3/sec or 74 cusecs). The sluice was again operated on 12 Mag to compensate for the opening of distributary canal 308-Dl and an increase in water issue to 305-D1; the water level at MS1 read 1.24 meters (4.05 ft) at the end of this maneuver. The corresponding flow in the branch canal was 2.15 m^3/sec or 76 cusecs. The target issue was again revised on 13 May on the assumption that the total anticipated area had now to b12 served and the main sluice was accordingly adjusted to record a water level close to the final target value of 1.3 meters (4.25 ft) at MS1 (i.e., 2.38 m^3/sec or 84 cusecs).

Besides the difficulties in assessing the actual issues released from the tank with some degree of accuracy, and the trial-and-error procedure involved in determining the correct gate setting corresponding to a target flow, interventions were also needed at the main sluice to maintain the target flow at the desired value as indicated in Table **IV.5.** These latter adjustments of the main sluice (roughly one per rotation) were usually necessary to compensate the flow variations resulting from water level variation in the Kalankuttiya Tiank.

In the course of yala 1988 a total of 106 interventions have been performed at the main sluice of the Kalankuttiya Tank. Thirty four (or 32 percent) of them correspond to openings and closures at the beginning and end of the different periods of water issue. Sixty three (or 59 percent) of them have been made in response to changes in targets while the balance nine (or nine percent) have been to compensate changes in tank water level.

Variations in tank water level. The variations of tank water level observed during the season have been in the range of 0.0 **to 0.26** meters per day (Figure IV.7; note that in this figure the recorded tank water levels have been multiplied by two to facilitate graphic representation). If no adjustments are made to the main sluice opening, a decrease in branch canal flow will occur due to the decrease in tank water level.

For example, between 0600 h on 27 July and 0600 h on 28 July the tank water level dropped from 2.23 meters to 2.04 meters - a variation of 0.19 meters - while there has been no adjustment of the main sluice gate. The flow in the branch canal at these same times as measured at the staff gauge MS1 had varied from 2.92 m^3/sec to 2.77 m^3/sec - a reduction of 0.15 m^3/sec. This corresponds to a rate of variation of five percent of the average discharge on this day.

The impact of the lack of main sluice operation on branch canal discharges can also be studied during the period between 19 and 25 August when the sluice gates were under repair. Between 0600 h on 20 August and 0600 h on 21 August the tank water level dropped from 2.81 meters to 2.55 meters. The corresponding change in branch canal was from 3.2 m^3/sec to 2.92 m^3/sec. This is a nine percent reduction in the average daily discharge occurred as a result of a 26-centimeter drop in tank water level.

During the study, carried out in yala 1988, it was observed that the level in the Kalankuttiya Tank varied continuously, depending on the timing and relative magnitudes of the inflow and outflow. But it has been possible to always maintain the tank water level above 1.52 meters (5 ft), which the agency considers as the minimum operating level, due to the relatively abundant water available in the Kalawewa Reservoir this season. It has been reported, however, that during the crisis situation associated with the maha 1986-87 drought, the water level in the Kalankuttiya Tank even dropped below 0.9 meters (3 ft) (Raby and Merrey 1989). Obviously the degree of control over the tank water issues under these latter conditions would have been poorer than that observed during the relatively favorable conditions of yala 1988. Two reasons could be attributed for this:

a) the limited capacity of the tank near the dead storage results in faster depletion of water level in the tank for the same issues, and

b) the sensitivity of the flow variation through the main sluice orifice increases considerably with the reduction of the operating hydraulic head over the orifice.

Poorer control over the tank water issues in a time of water shortage would have exacerbated the difficulties of water distribution along the branch canal and contributed to the overall downgrading of the manageability of the system as reported earlier.

<u>Preliminary conclusions</u>. The manageability of the system, as far as the control of water issues from Kalankuttiya Tank into the branch canal is concerned, is relatively effective, given the existing facilities and the operational arrangements. The agency tends to meet the target issues which they have defined. Some limiting factors are present, however, which can be attributed to:

a) inadequate planning and design that have resulted in the rather inconvenient arrangement for assessing the flow released at the head of the branch canal;

b) inadequate maintenance of essential structures such as the main sluice headgate; and

c) the level of performance achieved by the agency in the regulation of the conveyance system (i.e., the management capacity of the agency to maintain water levels in the Kalankuttiya Tank in an acceptable range by'timely refilling). This will be further discussed in Section 4.3.

Santo Domingo Area (SDA) Main Canal

Target flows. At the Upper Pampanga River Integrated Irrigation System (UPRIIS), the engineer in charge of the Water Central Coordinating Center located at the National Irrigation Administration (NIA) Project Headquarters, Cabanatuan, decides upon the actual water allocations within the main system and fixes the target flow to be met at key diversion points. The site locations and irrigation network have been shown in Figures 11.6, 11.7, and 11.8.

The Water Central Coordinating Center receives, from the district staff, all the information required to determine the necessary releases at any given time from the Pantabangan storage reservoir. In particular the Center, in consultation with the District Hydrologist, fixes targets in terms of

a) flow to be diverted at the Pampanga Diversion Dam (Rizal) through DC#1 - a major diversion canal which conveys the water to be shared between Districts I and II, and

b) flow allocated to each of the two districts.

Radial Gate RG#3 represents a key location in this respect as it is located at the boundary between the two districts and because water is first delivered to District II as it passes through it before reaching District I.

The Hydrologist of District I, whose office is located at Munoz, also plays a key role in the above water-allocation process coordinated by the Water Central Coordinating Center. He indicates to the Center the flow to be conveyed through DC#1 to serve the needs of his district. He conscientiously checks at RG#3 if the district 'for which he is responsible got its share of water and he would alert the Center if it did not. During the water-allocation process, he would also have determined the share of the targeted district flow that should be diverted at the SDA Supply Headgate, located toward the tail of DC#1 (Criterion A).

This last diversion is effected into the Sapang Kawayan Creek which drains water from a relatively large catchment area - the Upper Talavera River Irrigation System also of District I (Zones 1 and 2). The water diverted at the supply headgate and the local flow constitute the supply available for the irrigation of the SDA. This water supply is diverted from a creek into the SDA Main Canal at the 5-Bay Checkgate (see Figure II.8).

For most of the time, the SDA Main Canal draws all the water available in the creek at that location and there is usually no operation performed on the intake structure unless excessive runoff makes it necessary to discharge the excess flow in the creek through the spillway of the 5-Bay Checkgate built across the creek.

Communication of information and revision of targets. Hydrologists of the districts attend a weekly meeting with the Water Central Coordinating Center at Cahanatuan. This provides an opportunity for information exchange regarding the irrigation demand at the district level, status of the water resource and current policies of the Water Central Coordinating Center regarding the use of the resource. In addition, the hydrologists have the possibility to communicate with the Center in real-time, through a radio link. The Hydrologist of District I, in particular, informs the Center of any substantial rainfall occurring in the area that would justify a reduction of supply to the SDA.

It has been possible to observe and document such a sequence of events during the period between 12 and 16 September 1988. The physical observations were supplemented by the continuous record of water levels in the Parshall flume near the main canal headgate provided by the electronic data-logging equipment installed here. Figure IV.11 shows the schematic layout of this data-logging station. The hydrologist and the Water Central Coordinating Center were obliged to change the target flow in the conveyance system following substantial rainfall in the command area. This rainfall ended a period of relative drought that had prevailed since the start of the season. The week started with a reduced allocation of 10 m^3/sec to District I, of which 4 m^3/sec were meant for diversion at the supply headgate to complement a local flow estimated by the hydrologist to be in the range of 2 m^3/sec. Hence, a total target of 6 m^3/sec was supposed to be available for the SDA Main Canal at the 5-Bay Checkgate.

The hydrologist said that he was able to rely on his experience to estimate the local flow available in the creek before and after the rains. He also claimed that such a problem had been studied at the Water Central Coordinating Center on the basis of the flow-monitoring data at both ends of the creek which are communicated to their office. Similarly, the water requests made by the hydrologist to the Center does not seem to result from any systematic and analytical assessment of the demand in the SDA command area, but instead he seems to take into consideration the relative abundance or scarcity of water to formulate a realistic request that would have a chance of being fully met.

Thus, the zone engineer in charge of the area expressed the view that 6 m^3/sec was inadequate compared to the supply under normal circumstances that averaged 9 m^3/sec at the head of SDA Main Canal. It turned out that according to IIMI's own assessment, the actual flow delivered at that time had varied between 9 and 10 m^3/sec. This indicates either an underestimation of the local flow or oversupply from DC#1 or both, compared to the target.

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On 14 September, the SDA received heavy rain in the afternoon (51 mm at Baloc). The hydrologist immediately communicated this by radio to the Water Central Coordinating Center. But he also placed a standing request of 5 m^3/sec for District I to prevent DC#1 emptying which would otherwise require one or two days to refill. Out of this request, 2.5 m^3/sec were meant for diversion at the headgate to supplement a local flow estimated in the range of 3.5 m^3/sec by the hydrologist, hence a total of 6 m^3/sec at the main canal. IIMI's discharge record at that location (Figure IV.12) indicates that the flow reaches a peak of 12 m^3/sec during the night following the rain, before falling to 6 m^3/sec by mid-day on the 15th, to 4 m^3/sec on the 16th, and to less than 4 m^3/sec on 17 September 1988.

Means to control flows. Actual flows that are lower than the targets set for SDA Main Canal should be viewed in relation to the difficulties experienced by operation staff of the National Irrigation Administration in the regulation of the conveyance system, DC#1 in particular. It was observed for instance on 16 September, that the conveyance of water through DC#1 had been totally interrupted at RG#3 as a result of illegal operations on this regulator during the absence of the gatekeeper. A large section of DC#1 subsequently got emptied which would have increased the difficulties in maintaining a stable diversion of water at the SDA Supply Headgate as per the target of 2.5 m^3/sec. As a result of these conditions, there is presently a limited control over the SDA inflow which varies widely even within a day.

The operational difficulties faced by the agency in the regulation of flow through the conveyance system (DC#1) impinge on its capacity to meet its delivery target at the head of the SDA subsystem. But other practical problems which limit the capacity of the agency to assess and monitor the actual flow available at the head of SDA Main Canal should be mentioned.

Reliability of flow estimates. At the SDA Supply Headgate, the hydrologist established a measurement station with a calibrated staff gauge which permits him to assess the flow diverted from DC#1 into the creek; but for assessing the total flow entering the system at the head of SDA Main Canal, he relies on the indications given by the UPRIIS/NIA Water Measurement Table of July 1977, and on observations of the water depth in the Parshall flume installed there.

The direct measurements and calibrations performed by IIMI for the study at this location revealed significant discrepancies between the actual flow measured by current metering and the assessment of the same through the tables used by the agency (see Table IV.7 and Figures IV.13 and IV.14 pertaining to the calibration of the Parshall flume at the headgate). The values obtained from the table exceed the actual flow by 18–46 percent depending on the degree of submergence at the flume. It was observed that the flume was frequently submerged. This is most likely due to the siltation of the canal since its construction. Total submergence may also occur at low flows as a result of interventions at a check structure existing downstream.

The difficulty in estimating flow when the difference between water levels upstream and downstream of the flume throat approaches zero (i.e., total submergence), is clearly shown in the record of water levels and discharges between 1 and 3 October 1988 (Figure IV.15). This 'limits the reliability of the measuring device to correctly assess the inflow at the head of the subsystem,

This situation might account for the apparent lack of interest on the part of the agency to make use of the daily flow monitoring at the .head of the SDA Main Canal for operational purposes. On the other hand, if such information is to be used 'for operational purposes, it would require adjustments to the setting of the SDA Supply Headgate which is located at quite a distance from the 5-Bay Checkgate in response to the observations made at that point (about 20 km away by road). Apart from the hydrologist, whose duties include such monitoring, there does not seem to be a mechanism for the operation of the supply headgate (at DC#1) in response to feed-back from the 5-Bay Checkgate.

<u>Preliminary conclusions</u>. The NIA/UPRIIS seems to have an effective mechanism in place for monitoring the progress of cultivation and allocating water at the system level taking into account the water resource status and the hydrology. It also has the capacity to revise, almost in real-time, the water allocations within various reaches of the system. The implementation of the planned allocations, however, falls short of expectations.

The inability of the agency to regulate effectively the conveyance of water effectively along the diversion canal DC#1 was identified as a major constraint towards improving the management of the distribution of water in the SDA. This point will be discussed further in Section 4.3.

The manageability of the system with respect.to the control of the water issues at the head of the SDA Main Canal appears limited, given the existing facilities and monitoring practices of the agency, but with a potential for improvement.

Amongst constraints identified, and possible ways to relax them, there are:

a) The Parshall flume located at the head of the main canal is frequently submerged, thus limiting the reliability of assessment of the flow entering the main. canal,. Furthennore, it needs to be properly calibrated as the UPRIIS/NIA Water Measurement Tables of July 1977 was found to be totally improper for this particular device. IIMI, however, was able to significantly upgrade the calibration of the structure in the course of the study, and this is now readily available to the agency.

b) Feedback regarding the actual flow available at the head of SDA Main Canal is not presently considered when operating the supply headgate to SDA from DC#1. Improved monitoring of the flow at the 5-Bay Checkgate, upgraded communication procedures to ensure that this information is received (at least twice a day) by the gatekeeper in charge of the supply headgate on DC#1, and tighter supervision of the headgate to prevent unauthorized interventions appear desirable.

Rajangana Pilot Area: Distributary Canal 1, Left **Bank** Tract **2**

Means for flow control. The Rajangana pilot command area has been equipped in late 1987 with hydromechanical flow control devices at the head of the Distributary Canal 1 and **9** field channels that take off from this canal. The arrangement at the head of this subsystem consists of an automatic constant downstream level gate (AVIO type) that is intended to provide the requisite conditions for the correct functioning of a main baffle distributor (maximum capacity of 300 liters/sec) located downstream of the gate, function of which is to control the flow delivered into the pilot area. Figure IV.16 shows the layout of the measuring device (electronic datalogger and associated sensors) installed by IIMI at this location. IIMI also monitored water flows at the head of Distributary Canal 2 in Tract 2. This served as a reference to compare the impact of the hydromechanical equipment installed in the pilot area, The layout of the data-logging station installed at this location (referred to as the "control" area) is shown in Figure IV.17.

The change in mode of water delivery. At the planning and design stage of the Major Irrigation Rehabilitation Project, the Irrigation Department made a decision to introduce rotational irrigation in the Rajangana irrigation scheme. This was no: readily accepted by the farmers and it became evident that it would be difficult to respect the original objective of generalizing rotational irrigation for two reasons: a) the exceptional water resources presently available for the Rajangana irrigation scheme which benefits from the drainage water from the Mahaweli System H, and b) the well-established practice of farmers of continuous irrigation.

In 1986-1987, at the onset of the project implementation, the farmers mobilized themselves against the proposed replacement of the traditional 75-mm (3 inch) farm pipe outlet by 225-mm (9 inch) pipes intended for the rotational issues. This option was finally abandoned in the entire Major Irrigation Rehabilitation Project except for the pilot area, and this accounts for some of the difficulties observed at that level.

In fact, a technical assistant became involved in supervising the operations within the pilot project area although interventions at that level are usually the task of a work supervisor and a field irrigator. The intervention of the technical assistant was apparently required to handle the complaints of farmers regarding their difficulties to share water along field channels.

It is therefore important, in studying the pilot project, to dissociate the two aspects: a) the impact of the initial decision made at the planning stage with respect to the mode of delivery and the implications of this decision on the sustainability of the project, and b) the impact of the design option chosen for improving the control and the manageability of the distribution system. Only the second aspect is discussed in this study.

Actual flow delivered. From the start of the monitoring in early July 1988 to the end of July, the flow issued to the pilot area has been maintained at a reasonably constant value of 270 liters/sec (2.87 liters/sec per hectare for the 93 ha irrigated in the pilot command area), while during August a flow of around 210 liters/sec (2.23 liters/sec/ha) was maintained. This reduction in delivery is somewhat compatible with the reduced water requirements towards the end of the season. A detailed analysis of the water-level record available at the head of the pilot canal, however, indicates that some odd interventions occur at night. From the end of July 1988 until mid-August there has been a regular increase of the flow to the pilot area during the night. The flow was increased around 2200 h and restored around 0600 h almost daily during that period. This obviously implies the consent of the gatekeeper who has custody of the key of the baffle distributor.

These nocturnal interventions are clearly illustrated in Figure IV.18 which represents the water levels recorded at this site for the period 2-10 August. The sharp drops in the distributary canal water level recorded upstream of the baffle distributor are a result of opening the distributor gates (the fluctuations in level that take place on 4 August are due to deliberate changes in discharge effected to permit IIMI's gauging measurements). This is accompanied by a corresponding increase in water level downstream of the distributor and a resultant increase in discharge (of the order of 40-60 liters/sec over 8-10 hours) delivered in the distributary canal.

Information on water flows,, Assessing the flow at the head of the pilot distributary canal and setting it as per target is straightforward; the flows delivered are expected to correspond to the sum of the discharge values through each of the baffle distributor shutters, which are either fully opened or fully closed at any given time.

The baffle distributors or "modules" which equip the pilot area are calibrated in the manufacturing process according to specific dimensions and design standards. Therefore there is no need for prior calibration in the field or use of a table to assess the flow. Flows could be assessed directly and openly by agency staff as well as farmers.

The current metering carried out during the study at the head of the pilot distributary canal have permitted to confirm the accuracy of the flow delivered compared to the nominal value corresponding to the setting of the baffle distributor shutters, within a maximum error of plus or minus 10 percent. At discharge values higher than 150 liters/sec, the actual flow tends to be less than the nominal value, and vice versa.

Conditions for reliable estimates of water flow. Discrepancies between theoretical and actual flows occur if the water level control at the head of the baffle distributor is not strictly satisfied. The distributor is then unable to function properly as per design. The characteristic head-discharge relationship for the single baffle calibrated distributor shown in Figure 11.17 indicates that the following water level variations above the distributor sill could be tolerated by the XX1 type of distributor installed at the head of the pilot distributary canal (Qn refers to the nominal discharge):

	Qn-10%	Qn-5%	Qn	Qn+5%	Qn+10%
Water level above sill of baffle distributor (cm)	20	21.5	27	29.5	31

It is therefore important to analyze whether these conditions were met in the field.

a) Construction accuracy and supervision. At the head of the pilot area, the depth of water over the sill of the baffle distributor is effectively controlled by the automatic gate. The gate is designed to maintain the water level at the head of the pilot distributary canal constant, irrespective of the fluctuations of water level in the main canal. This required particular attention at the time of construction to ensure that the installation specifications were strictly respected. In December 1987, a short consultancy by the engineers of the manufacturing firm was organized by IIMI, although there was no provision for this in the pilot project implementation plan. It was found that the level settings of some of the concrete work did not conform to specifications'and had to be rectified to allow the correct installation of the gate. Adjustments required for the .joint installation of the gate and baffle distributor associated with it do not. tolerate errors of more than a few millimeters in levels.

b) Maintenance and maintenance skill. The balancing of the gate and fine adjustments were performed by the consultants at that time. But during the nest irrigation season, in June 1988, IIMI discovered that for some unknown reasons the automatic gate was no longer adjusted and apparently unbalanced.

Irrigation Department staff had also found that the head in the main canal was sometimes insufficient for the correct operation of the gate and decided to remedy the situation on 6 June by constructing a temporary check structure in the main canal to raise the water level at the head of the pilot distributary canal. This actually compensates for some unexpected head loss (around 50 cm) through the offtake - maybe due to some obstruction of the conduit.

Since then, the design arrangement in place at the head of the pilot area has been capable of effectively and automatically controlling the inflow to the pilot distributary canal without any gate adjustment by the agency. Even large variations of water level in the main canal such as that which occurred on 13 August 1988 for some unidentified and unexpected reason were successfully accommodated. Annex IV.1 documents the impact of such a perturbation in the main canal on water issues to both the pilot distributary canal (Distributary Canal 1, Tract 2) and the Distributary Canal 2 in Tract 2 used for comparison purposes (referred to as the "control" canal).

Preliminary conclusions. As far as the control of issues from the main canal to the pilot area is concerned, the manageability of the system appears high. The operations are limited to the initial setting of the baffle distributor shutters as per target owing to the hydromechanical devices installed at the head of the pilot distributary canal. This favorable situation in terms of simplicity of operations, however, should not hide the strict conditions which have to be met in terms of supervision and skill required at the construction stage and thereafter for the maintenance of the system.

Thus, the tentative evaluation of the manageability of the system referred to above on a purely operational basis, should be weighed against the capacity of the Irrigation Department to meet the high quality specifications required during the construction phase, and to undertake the necessary maintenance of the hydromechanical equipment. Obviously these conditions were not in place prior to the implementation of the pilot project and one may question the sustainability of this project unless specific effort is made by the Irrigation Department to address these issues.

Thus, in the context of an agency not familiar with the technology being tested, the initial operational concern which was to improve the manageability through a better control of water issues, has now shifted to another area which relates to management of the transfer of technology. There are a number of issues that have to be addressed in this context (e.g., communication of information, training) but these are beyond the scope of this study.

<u>Conclusions of Section 4.2.1</u>

* The concern to control the water issues at the head of the subsystems was identified as an important objective that motivates operations staff in all four subsystems studied. At this level, the notion of target delivery is meaningful to the operators. These targets are generally explicit (except in the case of the SDA), though seldom recorded as such in the files maintained by the agencies. They provide, however, a rationale for the operational practices at the headworks of main canals.

* The ability of the operators to achieve control of the water issues at the head of the canals studied, however, appeared highly variable. In this respect, the manageability of the systems was found to be adequate at the head of the Kirindi Oya Right Bank Main Canal and at the Rajangana Pilot Distributary Canal, fair (but still possible) at the head of the Kalankuttiya Branch Canal, but poor [and not possible) at the head of the SDA Main Canal.

* Two types of factors were found to affect the control of water issues at the head of the canal: 1) <u>intrinsic</u> factors of manageability such as the means to assess the flow delivered and the means available to adjust the flow, and 2) <u>external</u> factors that condition the possibility to control water issues, such as the supply at the place of delivery.

* Main storage reservoirs or intermediate tanks have proved to be effective in providing external conditions that are favorable for the control of the water issues at the headworks of the canals taking off

from them. This was illustrated in the case of the Kirindi Oya Right Bank Main Canal taking off the Lunugamwehera Reservoir and at Kalankuttiya, as long as the water level in the tank is adequate (above operational level). These conditions are considered as favorable because the range and the pace of the variations of the water level in the reservoir (or tank) are such that the operators can cope with this variability through their current operational practices. The SDA Plain Canal, on the other hand, is characterized by the absence of adequate intermediate storage capacity at the head and this was identified as the major constraint that inhibits the control of water issues to the subsystem downstream.

* Technology, however, can be harnessed to provide favorable external conditions required for the control of water issues. This was illustrated in the case of the design arrangement at the head of the Rajangana Pilot Distributary Canal. The automatic gate controls the water level downstream of itself, thereby creating conditions for the control of water issues that are similar to those associated with a reservoir. With this arrangement the main canal is, in a sense, made to play the role of a reservoir. The control of water deliveries into the pilot area, that commences with this type of level control, would work as long as there is sufficient water conveyed in the main canal.

* Regarding the intrinsic factors of the manageability at the head of a main canal, two aspects were found to be of particular significance: 1) the performance and convenience of the arrangements provided, generally through the design, for the assessment of the flow delivered, thereby providing the operator with the means to obtain feedback on the flow control process; and 2) the means available, and their convenience to the operator, for adjusting the flow.

* Various design and technological arrangements were found to be in use for the purpose of assessing the flow delivered at the head of the canals studied. All of them rely on pre-calibrated measuring devices: 1) the sluice gate orifice at the head of Kirindi Oya Right Bank Plain Canal, 2) the gauging station in the Kalankuttiya Branch Canal, 3) the modular shutters (baffle distributors) at Rajangana, and 4) the Parshall flume at the head of SDA Main Canal.

* The calibration of the measuring devices at the head of the main canals studied was found to be adequate, with the exception of the flume at the head of the SDA Plain Canal which was found to be inaccurate to a great degree and therefore unreliable. Although monitored by National Irrigation Administration personnel, it has been established that this particular device was not really used for operational purposes. Instead, an alternate gauging station located upstream, at the SDA Supply Headgate taking off DC#1, was identified as the operational location; this latter device was calibrated by the district hydrologist.

* Thus, the quality of the calibration of the existing measuring devices is a good indicator of the locations where an irrigation agency can and actually exerts control of the water issues.

* The initial calibration of these measuring devices and their maintenance thereafter was seldom carried out by the staff responsible for operations. Most' often, the calibration is performed by separate monitoring units of the agencies or by outsiders. For example, the Mahaweli Economic Agency-Flow Monitoring Unit at Kalankuttiya, by-products of the Training System for Water Management Technologists conducted during the early years of operations at the Upper Pampanga River Integrated Irrigation System and later by the district hydrologist, or calibration built into the fabrication of the baffle distributors at Rajangana.

* The manageability of the measuring facilities available at the head of the canals studied is a function of two conditions: 1) the reliability and sustainability of the calibration of the device, which is associated with a greater or lesser demand for the maintenance of the calibration, and 2) the convenience of the arrangement as an instrument to be used by the operator to adjust the flow to meet a target.

* An arrangement like the baffle distributor installed at Rajangana Pilot Area totally alleviates the need for calibration and offers the possibility - rare - for direct reading of the flow delivered. This information is openly available, not only to the operator, but also to other interested parties, in particular to the fanners. The operator also found the arrangement simple to operate as the shutters do not need to be adjusted, but can be directly set to the target flow (in steps of discharge of 10 liters/sec).

* An arrangement like the main sluice gate of the Kirindi Oya Right Bank Main Canal is also effective. The gate orifice was calibrated once by the Irrigation Department after construction of the canal and this calibration, which depends only on the gate characteristics, is likely to last longer than any gauging section in a canal. Here too the arrangement is convenient for the operator. The opening of the sluice gate corresponding to a given target flow is first computed depending on the prevailing tank water level. The opening of the sluice gate can then be set directly to the required value by means of a meter and an electrically powered command.

* The arrangement at the head of the Kalankuttiya Branch Canal might be considered less favorable because of the distant gauging station that permits to assess only a part of the water issued from the tank (the first two offtakes excluded). The calibration of the gauging station has to be verified from time to time by the Mahaweli Economic Agency-Flow Monitoring Unit. Furthermore, the setting of the gate is not a straight forward action as at Kirindi Oya, but an iterative process that requires a few maneuvers before the operator can meet a target flow.

* The design arrangement at the head of SDA (5-Bay Checkgate) is the least manageable, and is a likely reason for it being abandoned. If the flume were calibrated, the adjustment of the inflow to SDA to a given target would require the operator to follow a number of steps: two water level readings at the flume and the consultation of a table to assess

the flow; then assessing the local flow in the Creek by difference with the flow released from the DC#1, and then making the necessary adjustment at the SDA Supply Headgate situated more than 10 km from the 5-Bay Checkgate. As the local flow is likely to vary, this adjustment process would have to be repeated frequently not to mention again the constraint associated with the regulation of the supply through DC#1.

4.2.2 Control of Water Issues from Main Canals

Criterion A: Availability of operational targets for delivery

Kirindi Oya Right Bank Main Canal

The water issues to be made at the head of each canal (branch, distributary, or field channel) taking off from the main canal are computed on the basis of the seasonal irrigation schedule elaborated by the Senior Irrigation Engineer (Water Management). The Irrigation Engineer at the office of the Resident Engineer (Right Bank), computes the heights of water corresponding to the discharge planned at each offtake that should be maintained over the measurement weirs located at the head of each of these lower-order canals. The theoretical head-discharge relationship for free flow over a weir is used, irrespective of the physical and hydraulic conditions under which the weirs are functioning (the weirs are frequently damaged and/or submerged). Nevertheless, the field irrigators are expected to adjust the offtake gates to maintain these heights and respect the rotation schedule.

The actual operating procedure, however, differed considerably from the nominal one. Our observations revealed that adjustment of offtake gates is performed in response to the prevailing downstream demand/supply conditions of that canal. Adjustments are first made to the field channel offtakes in order to deliver adequate flows to the field channels. The higher-order canal (distributary or branch canal) offtake gate is then suitably adjusted to ensure that all field channels supplied by it do not suffer water shortage. Observations, however, indicate that the supply at the offtakes along the main canal varies continuously with the fluctuation of water level in the main canal.

The field irrigators are supplied with weekly schedules regarding the supply to be achieved at each offtake, in terms of water levels to be maintained above the measuring weirs at the head of each distributary canal or field channel. But these instructions are rarely followed. Ad hoc modifications are made depending on the actual field conditions as described above. For all practical purposes, the true objectives of the operators are not expressed in terms of a given flow to be delivered at the offtake but as an "equilibrium" to be reached (i.e., a no-complaints situation).

With experience, the field irrigators seem to have developed different kinds of references that reflect the status of the system which they know correspond to the no-complaints. situation. This includes marks in the main canal which represent, in general, a level in the main canal above full supply depth and corresponding marks in the lateral canals.

Preliminary conclusions. Target flows, as computed by the senior irrigation engineer, are not necessarily being respected; instead there seems to be a rather uncontrolled system of responding to demand2 at the level of the distributary canals and field channels.

Kalankuttiya Branch Canal

At. Kalankuttiya, the irrigation laborer responsible for the daily setting of distributary canal gates in Blocks **305** and **308**, as well **as** the setting of the tank sluice, knows the target flow to be issued for the day. This laborer meets the Irrigation Engineer, Galnewa, every morning between 0700 h and 0800 h for instructions on above tasks. Instructions are usually given in terms of relative gauge height corresponding to the intended flow at the different locations.

The daily report of this irrigation laborer to the irrigation engineer also provides the engineer with an opportunity to get some feedback regarding the supply to the three offtakes (306-D1, 306-D2, and 309-D1) located at the extremity of the canal section for which he is responsible (i.e., downstream end of the upper section of the branch canal). (See Figure IV:6.) These distributary canals are actually part of the Meegalewa Block but it seems that this irrigation laborer is purposely monitoring them on the orders of the Irrigation Engineer, Galnewa.

Such a procedure, involving daily instructions to the irrigation laborer regarding the target issues and feedback to the irrigation engineer, was apparently lacking for the lower section of the branch canal which Came under the administrative responsibility of the Meegalewa Block during yala **1988.** For different reasons, including distance to the branch canal and lack of personnel at the Meegalewa block office, neither the Block Manager nor the Irrigation Engineer was in a position to exert any authority in distributing water to this section for the last season. Therefore, the irrigation laborer in charge of the distributary canal gate operations in Blocks **306**, 307, and **309** was left on his own, with the initial irrigation schedule prepared at the start, of the season as the sole reference.

On the other hand, it is a common practice among irrigation laborers who operate field channels to request additional water issues. The request is channeled through the unit manager and conveyed to the block office with a "field note." These requests are generally for extension of the duration of supply but sometimes are for increased flow in the branch canal as well. The argument usually evoked is the need for completing the irrigation activities.

In yala 1988 for instance, there was a request for additional flow on the second day of the land-preparation period and at the end of this period a

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[2]The actual regulation of. the system appears ambiguous. At the tertiary level it tends to be demand driven while regulation of the main canal is generally supply driven.

special issue was made in response to a specific request from the tail end of the branch canal. Many other requests for extension of water issues were noticed during the season; the practice of the "field note" is a routine rather than an exceptional operation. During yala 1988 extensions were made' at the end of 8 out of the 13 rotations practiced.

In yala 1988 such requests were easy to satisfy because of the relative abundance of the water resource and because of the pattern of rotational issues adopted by the agency for this season - simultaneous issues to all distributary canals during three days and closure of the branch canal during the next four days. Hence, satisfying a request for extension of water issues was only a matter of postponing the normal closure of the distributary and branch canals. On the other hand, the duration of the rotations is also sometimes reduced, usually due to rainfall.

Preliminary conclusions. Explicit, supply-based operational targets for each rotational period are transmitted to the irrigation laborers who attempt to meet these targets. But these targets are sometimes modified, usually towards the end of the rotation, when farmers request extensions to the duration of water issues. These requests are generally granted by the management.

Santo Domingo Area (SDA) Main Canal

Observations carried out in the SDA indicate that monitoring is performed with respect to the interlateral weekly status of farming activities which are further aggregated at the division, zone, district, and project level. This information provides the material for the monitoring and evaluation tasks that are the core of the management activities at the project headquarters.

Operations staff within SDA also monitor daily discharges at the supply headgate, at the heads of major lateral canals (Laterals A, B, .F, and G), and the daily rainfall. This information, collected by the gatekeepers, is submitted through the water management technicians and zone engineer to the hydrologist or operations engineer. It is doubtful, however, whether this information is 'used for the day-to-day operations of the SDA subsystem.

The water resource at Pantabangan Dam had been scarce since the beginning of the season, and issues to SDA were discontinued. IIMI performed flow monitoring during the period July-September 1988 at Laterals B and G in addition to at the main canal headgate. Figure IV.19 is a schematic representation of the different measurement locations near Lateral B. Similar details for lateral G are shown in Figure IV.20. The continuous record of flows (Figure IV.21 and Table IV.8) at the branching point of Lateral B from SDA Main Canal for the period 21 July to 7 October 1988 indicates that the flow in Lateral B was generally below 2 m^3/sec at that location apart from the periods 25-30 July, 5-11 August, 17-26 August, and intermittent periods from 0'3-20 September which received more substantial issues.

After the long period of low flow that prevailed in August.-September, the zone engineer in charge of SDA (District I, Zone 3) had worked out a schedule to issue water between laterals in a rotation ranging from one to four days depending on the extent of the planted area in the lateral concerned. The schedule (Figure IV.23) was elaborated in consultation with the hater management technicians of the zone and with the farmer group leaders with effect from 12 September 1988.

It turned out that by the time the rotation was implemented, there had been some rain in the area (7 and 9 September) and more thereafter (14 and 17 September). Nevertheless, the rotation was implemented as planned and the records indicated that Lateral B was issued water strictly as per the agreed schedule from 0800 h on Monday 12 September to 0800 h on Wednesday 14 September. A second rotational issue took place from 19-21 September. Thereafter, attempts were made to continue the schedule of, rotations to Lateral B despite the limited water supply in the main canal.

Evidence of the irregularity of the flow entering the subsystem is provided 'by the records. These problems were already noticed at the head of SDA Main Canal, but the irregularities are amplified when moving down the system. At the Lateral B branching point, the only period which shows some stability in the flow was. between 19-23 August (Figure IV.21). At the Lateral G branching point, stability of inflow just does not exist escept at very low flows (Figures IV.22 and IV.25).

Given these conditions, the notion of target flow to be distributed in terms of absolute discharge values appears meaningless to the water management technicians. This was confirmed by the technician in charge of Lateral B who admitted that during the very short period available for the issue to his particular lateral (from Monday 0800 h up to Wednesday 0800 h), his strategy was to divert as much flow as the capacity of the canal permitted. The records show that the timing of the rotations implemented at Lateral B since 12 September was strictly respected and the diversion was achieved by checking fully the main canal.

But before the rotational issues took place the operators appear to have implemented another strategy - sharing the water flow in an acceptable proportion between Lateral B and the main canal below the branching point seems to have been the rationale for the canal operations.

For instance, during the unique period of relative stability of the flow in the main canal between 19 and 23 August, the proportion of the main canal inflow diverted into Lateral B was nearly 40 percent (Figure IV.24). It is remarkable to observe that for this particular period during which the operator was in a good position to control effectively the sharing of water, the division of flow between Lateral B and the main canal was nearly in the same proportion as the respective planted areas - the extent of 2,852 ha planted under Lateral B corresponds to 40.6 percent of the total planted area of 7,031 ha upstream of the cross-regulator.

But most of the time, the flow in the main canal is rapidly changing and the division of the inflow into the above proportion is difficult to achieve.

For instance, during the period from 24-31 July, the records (see Table IV.7 and Figures IV.26 arid IV.27) show that the operator had a difficult time trying to share out the inflow in the proportion of the areas served. The frequency distributions of the flow into Lateral B during the above period (Figure IV.28), derived from the discharge values recorded at 10-minute intervals. indicates that the flow division actually took place in proportion to the respective planted areas (i.e., 40.6 percent of inflow diverted into Lateral B) less than 35 percent of the time.

On the average over the entire period of measurement, from 21 July to 7 October 1988, Lateral B received approximately the same proportion of water 111.68 million cubic meters, or 40.8 percent, out of 28.58 million cubic meters available immediately upstream) compared to its share of the program 'area 140.6 percent) (see Table IV.8 and Figures IV.21 and IV.24). This is an estremely favorable result, given the physical cohditions of the control structures and the difficulties faced by the operator to divide the water. Some of these difficulties are discussed later on in this chapter.

Preliminary conclusions. It does not appear that the operations staff intend to control the flow distributed along the SDA Main Canal by reference to any predetermined target flow. Obviously this option does not seem practicable given the irregularities of the flow entering the system.

Instead of quantitative flow control, sharing whatever flow available in the proportion of the irrigated area appears to be the prevalent mode of operation of the main canal. In times of water scarcity, time-sharing was introduced as a more stringent method of control but with limited results in the absence of flow control at the head of the subsystem. These distribution practices constitute a substitute for any type of regulation based on flow control.

Analysis of the operations performed at the Lateral B branching point revealed that it has not been easy to manage the sharing of variable inflow between Lateral B and the SDA Main Canal given the existing design of the partitioning structure (undershot gated regulator).

Rajangana Pilot Area: Distributary Canal 1, Left Bank Tract 2

All field channels that take off from the pilot distributary canal (Distributary Canal 1, Left Bank Tract 2) are equipped with baffle distributors (or "modules") of 30 liters/sec maximum discharge capacity. By opening or closing one or more of the shutters of each module the field irrigator can adjust the flow to be delivered in steps of 5 liters/sec in the range 0-30 liters/sec. Hence, the actual target flows set by the operations staff are displayed openly. Anyone, farmers in particular, can check the value in respect of each of the field channels by direct observation.

However, this capability seems to have been overlooked by the agency. As a matter of fact, the proper functioning of this arrangement was disrupted in the case of three field channels located at the tail-end owing to inappropriate intervention for flow monitoring purposes. As a result, the initial capability to verify by direct observation the balance between the flow issued at the head of the subsystem and the flows distributed into the field channels was no longer possible. (These aspects are further commented upon later in this chapter.)

Conclusions, with respect to Criterion A; of Section 4.2.2

The four systems studied exhibit important differences with regard to this criterion, which is the availability of operational targets to control the water issued along the main canals studied.

One difference relates to the nature of the actual operational objectives considered in issuing water along the main canal. They may be formulated in terms of predetermined target flows to be issued, like in the case of Rajangana and Kalankuttiya, or in terms of a given share of the available flow at a time in the main canal, like in the case of the SDA.

Various degrees of difficulty are experienced in.maintaining these targets in the different canals studied. The design at the head of the canals taking off from the Rajangana Pilot Distributary Canal makes it relatively easy to respect the targets. In addition, adherence to the targets can be easily verified. On the other hand, farmer intervention appears to interfere with efforts of irrigation laborers in Kalankuttiya, while at Kirindi Oya, actual targets tend to be defined in terms of satisfying farmers' demands.

Another difference relates to the communication of information to and from the field when deviations from the operational targets occur. Upward communication of information leading to appropriate adjustments of the main sluice are *observed* at Kalankuttiya resulting in the extension of the rotational periods. This is sometimes observed at Kirindi Oya. But information on flow adjustments at the head of the system is hardly ever communicated downward (it is nil in the case of SDA) with the result that the necessary downstream operational maneuvers to respond to such changes cannot be carried out effectively and in a timely manner.

Criterion B: Availability of reliable water flow information

The capacity of the operators and irrigation agencies to adequately assess the flow delivered at the offtalres along main canals is important for at least two reasons: 1) as a condition to control the delivery itself at a given point, and 2) to be able to monitor the performance achieved in the primary distribution of water from the main canal over a period of time. These aspects are essential for the regulation of flow in a canal.

Kirindi Oya Right Bank Main Canal

The facilities provided by the design of the Kirindi Oya Right Bank Main Canal to assess the flow diverted from the main canal into the lateral canals are similar to those of Kalankuttiya Branch Canal. All 33 secondary canals that take off from the main canal are equipped with measuring weirs of different, width depending on the design capacity of the canal in question. A perforated baffle wall is located immediately upstream of the weirs in order to prevent turbulence and to increase the accuracy in measuring the depth of water over the weirs.

The physical condition of nearly 30 percent of the measuring structures has deteriorated, although the system is new and has been functioning for less than five seasons (Table IV.11). In particular, the baffle walls have proved to be very inconvenient and most of them have been broken either by farmers or sometimes even by the operations personnel of the Irrigation Department. The main reason for this is that the baffle wall tends to act as an obstacle especially when blocked by weeds. This creates additional head losses, further limiting the total head available to divert the required flow even €or the maximum opening of the offtake gates. Given the gentle topography of the system, the maximum head available above the weir crest appears insufficient in many places. This is the likely explanation for the destruction of about 50 percent of the measuring weirs within Tracts 1 and 2 at times of water scarcity when it might have been difficult to maintain full supply depth in the main canal.

Furthermore, from a hydraulic point of view, many of these measuring weirs appear to be fully submerged at the nominal capacity, making flow assessment through the current practices of the agency questionable. Irrigation Department staff use the theoretical head-discharge equation to transform measured depth over the weir into discharge values. This results in a general <u>overestimate</u> by the Department of the flow diverted at the offtakes. A discussion on the differences in discharges computed at the head of Branch Canal 2 by the free-flow head-discharge equation for the weir and the IIMI method which uses the offtake gate opening and the differential head through the orifice is presented in Annex IV.2.

Overestimation is often due to assessing flow at the measuring weir while the water surface has been raised above the critical depth because of backwater effects. The Irrigation Department is presently in the process of replacing the existing measuring devices with: broad-crested weirs (see below) that are reputedly less vulnerable to the effects of submergence. In any case, the Department's monitoring exercises do not seem to be used for any operational purposes as yet.

The difficulties referred to above have been analyzed in detail at the two laterals selected for the study, Distributary Canal 5 in Tract 1 and Branch Canal 2 in Tract 5. Figures IV.34 and IV.35 show the locations of these sites. The crest of the weir of Branch Canal 2 was in good condition while that of Distributary Canal 5 had been damaged and the crest partially lowered. Both weirs were found to be submerged at full flow (approximately 400 liters/sec for Distributary Canal 5 and 1,200 liters/sec for Branch Canal 2). Furthermore, it was reported that when setting out the proposed broad-crested weirs it was discovered that the existing bed level of Branch Canal 2 was about one foot (0.305 meters) higher than the design value. Similar observations have been reported since IIMI provided the Irrigation Department with a topographical survey that it commissioned for the purpose of establishing a mathematical flow simulation model of the Right Bank Main

Canal. These findings have attracted the attention of the Department to the problem of the quality of the construction of the Kirindi Oya Project (e.g., the quantum of excavation actually carried out which does not seem to have been checked for conformity to the design).

A sample analysis of the records at Branch Canal 2 from 27 to 28 March 1988 (Annex IV.3) indicates the resulting error currently made in assessing the flow in it by two methods: 1) based on the depth of water over the weir, and 2) by employing the offtake gate openings and the continuous records of water levels upstream and downstream of the gate orifice. During this period, the overestimate in flow ranges between 17 and 25 percent for discharges above 1.5 m^3/sec while the error was almost negligible for flows below 1.0 m^3/sec given the downstream condition of the system at that time.

Further investigation revealed that a gate existing across the branch canal at a drop structure about 100 meters downstream of the measuring weir was sometimes operated in order to raise the head within the reach of Branch Canal 2 and increase the supply into Distributary Canal 8 and Field Channel 6 (see Figure IV.36 for relative locations of these structures). It has been observed that the closure of this checkgate was responsible for the backwater and submergence of the measuring weir even at low flows.

For example, around midnight on 27 April, this gate had been closed with the intention of reducing the flow diverted into Branch Canal 2 while it was not possible to intervene on the offtake gate of the canal itself. This is clearly visible in the water level record indicated in Annex IV.2. The consequent rise in branch canal water level at the measuring weir will be interpreted as an increase in branch canal discharge if the Irrigation Department's free-flow head-discharge equation is used for computation. On the other hand, the fact that the backwater effect would cause a net decrease in branch canal discharge is correctly brought to light if the IIMI equation for the Branch Canal 2 offtake orifice is employed. Details of this and similar episodes that illustrate the' impact of using the free-flow weir equation for computation of discharges into the branch canal are also given in Annex IV.2. The senior irrigation engineer is well aware of the above problems that limit the capacity of the agency to correctly assess the flows diverted at the offtakes. A prototype of the modified broad-crested weir has been tested and plans are underway to replace all the existing measuring weirs and baffle wall arrangements, which the fanners sometimes perceive as obstructions to obtaining adequate flow in their canals, by this structure. Although the new structures might well tolerate a greater degree of submergence than the existing structures without discharge being adversely affected, this advantage might be nullified if the weirs are fully submerged as it seems likely to happen given the topography of the canal bed.

Preliminary conclusions. The poor physical condition of 'the measuring weirs does not permit reliable assessment of the flow at nearly 30 percent of the canals that take off from the Kirindi Oya Right Bank Main Canal. Most of the weirs are, in addition, frequently subjected to submergence. Under these circumstances, assessment of flow assuming free-flow conditions has been shown to lead to overestimation. The Irrigation Department expects more reliable flow information once the present weir-box type of measuring devices are replaced with modified broad-crested weirs, reputed to be less vulnerable to submergence. But the problem might persist unless additional hydraulic head is provided by suitably altering the profile of the canal bed.

Kalankuttiya Branch **Canal**

Mast of the 20 distributary canals along the branch canal are equipped with measuring devices consisting of a broad-crested weir and associated measuring scale, commonly referred to in the project as a hump gauge, located in a weir box at the head of the canals. These facilities make it possible to assess the flow over the weir by means of the appropriate head-discharge relationship for free-flow condition. Such relationships (usually in the form of a calibration curve) should be established through field measurements of head and flow (by current-metering). The Flow Monitoring Unit attached to the Resident Project Manager's Office at Galnewa assists the irrigation engineer in charge of the branch canal by developing *and* updating the necessary rating curves.

During the period of irrigation, gauge readings at the heads of distributary canals are monitored by the irrigation laborers of each block (Galnewa and Meegalewa) on a daily basis. The irrigation laborers sometimes adjust the offtake bate openings if they observe that the water levels in the distributary canals (expressed in terms of head over the weirs) show deviations from the target values given to them. But the laborers record the' gauge reading after any adjustment they might have performed, with the result that the agency records would generally show **exact** compliance with the targets. The monitored readings are subsequently converted into discharge at the project office. This conversion is performed on the assumption that free-flow conditions prevail at all the locations at all times, which is not necessarily true.

At the time of the study, all the offtake gates (steel sluice gates with a manually operated screw type lifting device) along the branch canal were in working order. But only 85 percent of the crests of the weirs were in good physical condition. Our observations indicate, however, that only 30 percent of the weirs actually function under free-flow conditions at all times. Forty percent of them are subject to submergence from time to time for various reasons, and 15 percent are submerged at all times. Even though the weir is physically intact and the hydraulic conditions are satisfactory, measuring gauges are sometimes missing. Taking all these factors into consideration, the final assessment made during yala 1988 of the capacity to assess flow into the distributary canals is as follows: (See also Table IV.10)

- No possibility to assess flow delivered: **35** percent.
- Unreliable assessment: 40 percent.
- Possible assessment: **25** percent with a sensitivity of around **20** percent (relative variation of discharge for a variation of 1-cm read at the measuring scale).

These observations are in keeping with previous reports indicating that ". . . at the lower level of the agency clearly there is a suspicion and distrust of the gauge readings by the irrigation laborer . . ." (Raby and Merrey 1989).

The reasons for the inadequate hydraulic controls for the assessment of flow are numerous:

1) At some distributary canals, the head available between the crest of the weir and the bed of the canal was found to be insufficient compared to the capacity of the canal (e.g., less than 0.25 meters for Q = 0.2 m^3/sec); this was either owing to topographical conditions that impose a limited longitudinal slope on its profile, or due to secondary raising of the canal bed as a result of siltation.

2) At other distributary canals, it is not uncommon to observe that the submergence of the measuring weir is a temporary phenomenon created by the operation of a structure located downstream (e.g., gate to provide additional head to field channels, culverts, etc.). In such cases the design inconsistency (excessive flexibility) appears to be responsible for the difficulties encountered in correctly assessing the flow.

The temporary nature of the difficulties faced in *some* canals is well illustrated by the observations made at Distributary Canal 308-D2 during yala 1988. Following the traditional **bethma** (share-cropping) practice, part of the command area supplied by 308-D2 was not irrigated during yala 1988. Thus the culvert located about 40 meters downstream of the weir was closed during this season. This has consequently led to a rise in the water surface in that reach which in turn led to submergence of the measuring weir at the head of 308-D2. In this case, the agency had temporarily lost the capacity to assess the flow of 308-D2 during yala 1988 with the facilities initially provided by the design. But this capacity is likely to be restored in maha when the entire command area is irrigated and the culvert is left open.

In order to assess the flow at the offtake of Distributary Canal 308-D2 for the purposes of this study, additional information had to be utilized - the offtake gate opening and the hydraulic head over the orifice of the gate. The gate openings were monitored by IIMI field staff while hydraulic heads were derived from the water-level records obtained by the data-logging equipment installed by IIMI at this location with sensors in the branch canal and immediately upstream of the weir at the head of the distributary canal.

Figures IV.29, IV.30, and IV.31 describe the physical layout at the dab-logging station established by IIMI near the first duckbill weir to monitor water levels in the branch canal a3 well as in Distributary Canals 305-D3 and 308-D2. The data gathered at this location, supplemented by the results of the monitoring of gate operations at the two distributary canal offtakes, bring to light the contrasting hydraulic conditions prevailing at the heads of these two distributary canals. These conditions (i.e., whether or not free-flow conditions prevail) in turn, affect the control of flow diverted at the offtakes.

The difficulties experienced in the control of the flow diverted at the offtake due to submergence are illustrated by comparing the records of water level obtained at the head of Distributary Canal 308-D2 (subject to submergence) and at 305-D3 (not affected by submergence) during two periods of rotational water issue, 21 to 25 June 1988 and 28 June to 2 July 1988. Figures IV.32 and IV.33 show that both the number of interventions and the resulting changes in water level (and hence flow diverted) are greater in the case of 308-D2 than in 305-D3, although in both cases there was no change in the level of water in the parent canal due to the effective level-control performed by the nearby duckbill weir, DBW#1.

Preliminary conclusions. The availability of reliable information regarding the distribution of water flow along the Kalankuttiya Branch Canal is determined by three conditions to be met simultaneously: a) the physical condition of the measuring weirs at the head of the different distributary canals, b) the presence or absence of a measuring gauge, and c) acceptable free-flow hydraulic conditions at these locations. An evaluation conducted on this basis revealed that reliable flow information can be obtained in respect of 25 percent of the distributary canals. Another 40 percent yield questionable flow information while there is no direct possibility for the operator to assess flow in the remaining 35 percent of the channels.

The difficulties in assessing flow have been shown to be sometimes of a temporary nature, due to occasional submergence of the measuring device as a result of seasonal intervention at a regulating structure situated immediately downstream.

Santo Domingo Area (SDA) Main Canal

The main lateral canals along SDA Main Canal are equipped with standard concrete Parshall flumes designed to permit the assessment of the flow diverted. The flumes are of different widths and assessment of flows diverted at the lateral is usually done on the basis of the depth of water measured upstream of the throat of the flume. These values have to be used in conjunction with the UPRIIS/NIA Water Measurement Tables of July 1977 (the Hydrologist of District I, had a printed copy of this document which he used to carry with him to the field). The tables also provide the reduction factors to be applied to the flow, depending on the degree of submergence of the flume which is a function of the ratio between downstream and upstream water levels measured at the flume.

Detailed observations regarding the hydraulic conditions prevailing at the flume of Lateral B, at Lateral G, and at the main flume at the head of SDA Main Canal have been possible during the irrigation season 1988, on the basis of upstream and downstream water level records. These observations are as follows:

1) The submergence of the measuring devices is prevalent. It has been seen at Lateral B, and was also frequently observed at the head of the SDA and even more often at Lateral I. Depending on the degree of submergence (defined as the ratio between downstream and upstream water depths at the flume) an appropriate reduction factor could be applied to the free-flow

estimation of discharge. But sometimes 100 percent submergence might occur, in which case estimation of flow is not possible. An example of such a situation occurred between 1 and 3 October 1988 at the SDA Supply Headgate, and has already been discussed in Section 4.2.1.

2) Use of the UPRIIS/NIA Water Measurement Tables of July 1977 for estimation of flow through the Parshall flumes is not always reliable.

For esample. application of the UPRIIS/NIA Water Measurement Tables of July 1977 to the Parshall flume located at the head of the system leads to a systematic overestimation of the measured flow values in the range of 18-46 percent. This phenomenon has already been referred to in Section 4.2.1 (see also Table IV.7 and Figures IV.13 and IV.14 pertaining to the calibration of the supply headgate flume).

Similar comparison performed at the Parshall flume of Lateral B indicates that the error in using the UPRIIS/NIA Tables would be in the range of -10 prcent to t37 percent with respect to the measured flow values in the normal range of operation (see Table IV.12 and Figures IV.37 and IV.39 pertaining to calibration of Lateral B flume). Over the period 21 July to 7 October 1988, computation of flow on the basis of the UPRIIS/NIA Tables would lead to an overestimation of 3.7 percent of the volume actually delivered into the Lateral B (i.e., 12.11 million cubic meters against 11.68 million cubic meters) (see Table IV.14).

Regarding the Parshall flume at Lateral G, the comparison of measured flow with those estimated using the UPRIIS/NIA Tables gives much greater discrepancies (see Table IV.13 and Figures IV.38 and IV.40 pertaining to calibration of lateral G flume). Field observations and the difficulties in establishing a coherent calibration curve that makes use of <u>all</u> the measured points, however, suggest that the flow at this flume is frequently submerged. The degree of submergence could not be quantified because water depths downstream of the throat were not monitored. Hence, flow estimations by both methods (UPRIIS/NIA Tables and IIMI rating curve) assume that free-flow conditions prevail at that location, which might not always be true. The computation of volume delivered into the Lateral G over the period 5 August to 7 October 1988 (Table IV.15), however, indicates that use of the UPRIIS/NIA Tables would have <u>overestimated the **supply** by over 100 percent compared to</u> the value calculated on the basis of the calibration carried out in the course of *this* study (i.e., 2.63 million cubic meters against 1.28 million cubic meters).

In all these cases, the differences observed cannot be explained by deviations in the actual dimensions of the flume with respect to the standard Parshall flume design. The following table compares the design and actual dimensions, as constructed, of the Parshall flumes:

Table IV.16. SDA: Comparison of theoretical and actual dimensions of concrete Parshall flumes at the Supply Headgate and Laterals B and G.

Throat (ft)	Width (cm)	A (cm)	B (cm)	C (cm)	D (cm)	F (cm)	G (cm)	K (cm)	N (cm)
15	456	778.0	760.0	548	760	122	305.0	23.0	46.0(T)
	454	776.0	769.0	546	764	121	307.5	23.5	44.1(A)
	(Headgate)								
10	305	435.0	127.0	366	473	91	183.0	15.0	34.0(T)
	303	442.5	433.5	375	476	91	177.5	16.5	32.5(A)
	(Lateral B)								
4	122	183.0	179.0	152	193	61	91.0	8.0	23.0(T)
	123	183.0	182.5	159	195	60	88.0	8.5	23.5(A)
	(Lateral G)								

Notes: 1. (T) = theoretical and (A) = actual.
2. Dimensions A-N correspond to the dimensions indicated in the design drawing of standard Parshall flume.

Though the physical dimersions of the flumes agree with the theoretical values. it is not clear whether the UPRIIS/NIA Water Measurement Tables have been verified under the present field conditions which might be quite different from the conditions that prevailed at the time when the water measurement tables were established. For example, the canal beds downstream of the flumes maybe silted, and/or the regulating structures after the flumes maybe operated at elevations higher than originally planned.

Preliminary conclusions. The concrete Parshall flumes installed at the head of the lateral canals of SDA Main Canal conform to the standard design as far as the physical dimensions are concerned. Their hydraulic functioning, however, has been found to be different from what is assumed in the UPRIIS/NIA Water Measurement Tables, at least in the study locations. Furthermore, the flumes at the supply headgate, Lateral B, and Lateral G have been found to be frequently submerged. Using these devices in conjunction with the UPRIIS/NIA Water Measurement Tables to assess flow generally overestimates the actual flows to a large extent.

Rajangana Pilot Area: Distributary Canal 1, Left Bank Tract 2

The distribution of flow amongst the field channels that take off from the pilot distributary canal is controlled through baffle distributors or "modules" similar to the one installed at the head of the distributary canal. but of smaller capacity 130 liters/sec).

As mentioned earlier in this chapter, assessing the flow delivered to each field channel through the calibrated distributors is expected to be direct. Simply adding the nominal discharge values marked on the open shutters at any one time would yield the total discharge being delivered, provided that the hydraulic conclitions required for the correct functioning of the module are met.

If so, the modules are supposed to contribute two important elements to the manageability of the system: 1) open access to the information regarding the flow delivered at the various field channels to anyone and in particular to the farmers, and 2) easy control of the water distribution within the command area by rapid water balance computation - the inflow issued into the distributary canal (corresponding to the setting of the main module) should be at least equal to the total outflow delivered to the various field channels, assessed by summing up the values corresponding to the open shutters.

Whether the hydraulic prerequisites referred to above were satisfied during yala 1988 and whether the irrigation agency derived any benefit from the additional capability provided by the technology is briefly discussed below.

As indicated earlier, the variation of head of water over the sill of the module must be limited within a narrow range to permit the module to deliver the nominal flow. In the case of the 30 liters/sec modules, a 5-cm head variation will maintain a discharge within plus or minus 5 percent of the nominal value, while a 7-cm variation will maintain a discharge within plus or minus 10 percent of the nominal value. This level control at the head of each field channel is achieved by means of regulating weirs built across the distributary canal. The length of the weir (duckbill weir type) was designed in accordance with the required accuracy of level control (maximum overflow height over weirs does not exceed 7 cm). One of the tasks performed by IIMI through the consultants in November-December 1987 was precisely to check the setting of the sill of the modules with respect to the 'crest of the regulating weirs.

This postconstruction checking appeared to be critical for the performance of the pilot experiment as many errors were corrected at that time except for some, such as an inappropriate location of a weir with respect to the field-channel offtake, and the absence of a module to control 'the flow of the tail-end field channels.

Subsequently, during yala 1988, it was observed that the level control achieved by the regulating weir was effective in the case of six field channels out of the nine that take off from the distributary canal. The water surface elevation upstream of the modules was maintained within the acceptable range and the flow delivered in these field channels was considered to be equal to the nominal values. It was not possible, however, to verify this assumption by current metering.

It was also discovered that an alterations made by the agency to the

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[3]The unfortunate intervention at the tail end of the distributary canal referred to above actually reveals a lack of understanding of the design of the pilot project. This is one of several deficiencies that have been identified in the conduct of the pilot project since the formulation of the project and the definition of its objectives, the understanding of the design concepts underlying such a pilot project, up to the project

design had detrimental consequences for the operation of the pilot project. This intervention took the form of a reduction of the width of the last regulating weir which increases the head at three tail-end field channels, and was reportedly made for the purpose of some flow monitoring needed at the tail of the distributary canal. By doing this, the agency transformed the regulating weir, whose performance requires a large width, into a measuring weir where a narrow width is preferable. As a result, the impact of the calibrated distributors at the head of the last three field channels on flow control at the tail of the pilot distributary canal has been totally negated. Furthermore, it takes away the possibility for the agency to perform direct monitoring and simple control cf the distribution (water balance between inflow and outflow) which cculd have been otherwise performed easily and reasonably accurately.

On the basis of the observations made on 25 May 1988, and with the use of the rating curves provided by the manufacturing firm of the modules

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construction and supervision of installation of the equipment and appropriate operations. These can be summarized as follows:

a) poor appreciation at the policy-making level of the difficulties to introduce rotational irrigation in a relatively water surplus environment where farmers had been accustomed to continuous supply of water since the inception;

b) misunderstanding of the basic objective of the pilot project and the associated role of canal regulation in improving the manageability of the system; on many occasions IIMI researchers had to remind the Irrigation Department staff that the primary focus of the pilot experiment was on improving the manageability of the system rather than on water saving;

c) lack of prior information and training regarding the innovative aspects of the design to be tested, its strict hydraulic requirements, the implications for the supervision of construction and installation, and for the maintenance of the equipnent. It was observed in 1987 during the project implementation that no officer, at project, range, or even at the headquarters level, had received the least technical documentation or information regarding the proposed control technology; **and**

d) inadequate expertise available to advise the department in the implementation of the pilot project and its operation; even the consultant supposed to cater to this task had no knowledge regarding the technology to be tested and the manner in which it should be operated.

IIMI's initiative, in late 1987, to bring in additional expertise from the manufacturing firm (ALSTHOM-FLUIDES, France) to guide Irrigation Department staff in the installation of the new technology was definitely opportune to make the equipment work, at least initially, but this could not compensate for all the shortcomings quoted above in the planning, design, and implementation of the pilot project.

(Figure II.17), a tentative water balance of the distribution of water along the pilot distributary canal was prepared to illustrate the consequences of the design alteration (Table IV.17):

Table IV.17. Rajangana: Water balance of distribution of water along pilot distributary canal, 25 May 1988.

	Shutter setting (liters/sec)	Discharge estimate (liters/sec)		
Inflow				
DC[a]1	270	260	1270 - 4%)	(6.5 cm below n.l[b])
Outflow				
FC[c]7	30	30		(n.l)
FC8	20	20		(n.l)
FC9	30	30		(n.l)
FC10	20	20		(n.l)
FC12A	25	25		(n.l)
FC12	30	30		(n.l)
FC13	5	7	1 5 t 0%)	(13 cm above n.)
FC13A	15	21	(15 t 40%)	(13 cm above n.l)
FC14	20	28	(20 t 40%)	(13 cm above n.l)
FC15	No module	47	(computed with the constricted weir formula; width = 50 cm and depth above sill :14 cm)	
		Total = 258 liters/sec		

[a]Distributary Canal.
[b]Nominal level.
[c]Field Channel.

Notes: i) Infiltration losses have not been taken into account, but the distributary canal is relatively short.

ii) The theoretical rating curve for the baffle distributor has been used to assess flow delivered under non-nominal conditions of level.

Conclusions, with respect to Criterion B, of Section 4.2.2

The availability of reliable flow information is a fundamental requirement for the control of water delivery from main canals, and which cannot be overlooked.

A number of practical problems that render difficult the correct assessment of flow have come to light in the course of this study, hence, limiting the capacity of the agency to control the delivery. Some of these problems are related to the deterioration in the physical condition of the measuring device and associated gauge, while others are more of a hydraulic nature. The latter problems are of two types: a) use of an improper head-discharge relationship, or b) impossibility to obtain a head-discharge relationship due to permanent or temporary submergence of the measuring device following intervention at a regulating structure situated immediately downstream.

Assessment of flow without due recognition of the existence of these hydraulic phenomena leads to unreliable information on the water issues.

Criterion C: Availability of means to influence water issues

Kirindi Oya Right Bank Main Canal

The design of the Right Bank Main Canal provides the following facilities for altering the flow diverted off the main canal:

1). the gate of the offtake (one gate per lateral in general), and

2) the gates at the cross.-regulator immediately downstream (one to five gates depending on the capacity of the main canal at that location); the variations of head in the main canal associated with the variation of inflow and the operations at the regulator affect the flow into the lateral. Most of these cross-regulator gates are still in working condition.

There is a lateral canal.immediately upstream of each of the 14 cross-regulators built along the 24.5-km right bank main canal. These are either a branch canal, a distributary canal, or a field channel, depending on the size of the command area served. There are 19 other distributary canal and field channel offtakes, but they are located at some distance upstream, from 200-2,000 meters, of the closest regulator (see Table IV.11).

Offtakes located far upstream of the regulators are expected to be more sensitive to the variation of water level in the main canal than those which are close to a regulator. This is demonstrated in Figure IV.41, which shows the variation of the water surface profile in the canal reach between gated cross-regulators GR12 and GR13 for different values of main canal flow at GR12 (0.5 to 3.5 m^3/sec) as simulated by the mathematical flow simulation model of the Kirindi Oya Right Bank Main Canal. These water surface profiles have been obtained under the hypothesis that the water level at GR13 is maintained at full supply depth (FSD).

The water level at the cross-regulator itself,' however, could be expected to deviate from full supply depth under normal operating conditions. Figures IV.47 and IV.18 indicate the observed frequency distributions of water levels at GR12, based on continuous datalogger records at this location over the period March-June 1988. The range of variation in water level corresponding to the interquartile interval (i.e., between the 75th and 25th percentiles which, in the case of GR12 are, respectively, FSD-3 cm and FSD+10 cm) is 13 cm.

We shall assume that the variation in water level at gated cross-regulator GR13 is the same as that at the adjacent regulator GR12 (i.e., from FSD-3 cm to FSD +10 cm, or 13 cm). The range of variations in water level (Delta H) that could he expected above the pipe invert levels of each of the five offtakes situated in this reach in response to main canal discharge values from 0.5 to 3.5 m^3/sec at GR12 is obtained through different, simulations and is indicated in Table IV.18 and Figure IV.42. The relative range of water level variation with respect to the mean head expected at each offtake is also computed and is expressed as a function of the distance of the offtake from the regulator in Figure IV.43. The variation in hydraulic head in relation to the proximity of the offtakes to the downstream gated cross-regulator GR13 is clearly visible - the offtakes located further away from GR13 are more vulnerable to fluctuations in the main canal water level. The implication for control of water delivery at the offtakes is that the intensity of interventions necessary at those offtakes which are reasonably well-regulated (i.e., limited relative range of water level fluctuation in the parent canal) is less than at offtakes which are subject to a large relative range of variation in water level in the parent canal.

Table IV.18. Simulated water level variation in reach GR12-GR13, Kirindi Oya Right Bank Main Canal.

Offtake	Diameter (m)	Invert level (m)	Distance from GR13 (m)	Minimum water level (m)	Maximum water level (m)	Range of water level variation ΔH (m)	Mean water depth (H) above invert level (m)	Relative range ΔH/H
FC[a]48	0.30	38.00	1992	38.629	39.234	0.605	0.931	0.649
FC49	0.30	38.03	784	38.581	38.859	0.278	0.690	0.403
DC[b]9	0.45	37.98	402	38.579	38.775	0.196	0.697	0.281
FC54A	0.30	38.06	242	38.578	38.735	0.157	0.596	0.263
FC54	0.30	38.01	6	38.578	38.706	0.128	0.632	0.203
GR13	-		0	38.573	38.703	0.13	-	-

[a]Field Channel.
[b]Distributary Canal.
[c]Elevation of crest of side check-wall = 38.60 meters (full supply depth)
Minimum water level corresponds to Q=0.5 m^3/sec
Maximum water level corresponds to Q=3.5 m^3/sec

This study is limited to observations at two branching points only, both located near a cross-regulator. Branch Canal 2 in Tract 5 is 48 meters away from the gated cross-regulator GR12 in the tail portion of the Right Bank Main Canal and Distributary Canal 5 in Tract 1 is 45 meters upstream of the gated cross-regulator GR3 at the head of the system.

The following analysis relates to a situation whereby the joint operations at a cross-regulator and at its neighboring offtake tend to determine the flow diverted into the offtake through the control of the hydraulic head in the main canal, irrespective of possible changes in the flow of the main canal.

In such situations, the field irrigators operating the diversion structures along the right bank main canal arbitrate between different operational options to achieve an intended diversion. The following practices were observed:

First type of operations: the most frequent type of operation. One or more gates at a cross-regulator are operated while keeping the gate of the lateral in the same position. Thus, the flow diverted is controlled indirectly through the control of the water level in the main canal. This practice is consistent with the standing order of the agency to maintain the level upstream of the cross-regulators at full supply depth. By doing so, the field irrigators aim to maintain in the main canal a certain head over the inlet of the lateral, the gate opening of which was initially set by reference to some appropriate "spindle length" known to the operator from experience as being able to provide the intended supply; or by trial and error.

In operating the cross-regulators the irrigators do not always maintain the same openings at all the gates of a given regulator. Instead they tend to always operate only one or two of the gates (usually the ones that are easier to operate). This practice could give rise to unfavorable hydraulic conditions that might be a contributory factor to the erosion of the canal bed and banks occurring immediately downstream of the regulators.

. At Distributary Canal 5, it appears that the effective head which commands the flow to the channel (difference in water levels on either side of the offtake orifice') was generally maintained within a range of 20 to 30 cm. This is illustrated by the Right Bank Main Canal water level record near the offtake of Distributary Canal 5 for the period from 12 May 1988 onwards corresponding to the start of the second irrigation season in Tract 1 (Figure IV.44). After a few initial changes in the opening of Distributary Canal 5 on.12 and 13 May (for cleaning the canal), the gate of Distributary Canal 5 was not operated any more until 28 June 1988.

It was also observed at various locations, and at Distributary Canal 5 in particular, that field irrigators actually maintain a level in the main canal which is higher than full supply depth. In the case of Distributary Canal 5 and Branch Canal 2, the water level at the two gated cross-regulators (GR3 and GR12 respectively) that control hydraulic head at these offtakes is most frequently maintained about 4 cm above full supply depth (FSD+4 cm). Figures IV.15, IV.46, IV.17, and IV.48 indicate the frequency distributions of main canal water levels (excluding the period of canal closure in mid-April 1988) at these two locations. The interquartile range of level variations at Distributary Canal 5 and Branch Canal 2 are FSD-6 cm to FSD+4 cm at Distributary Canal 5 and ED-3 cm and FSD+10 cm at Branch Canal 2. Maintaining water levels above full supply depth will allow larger flow to be diverted into the lateral canal compared to its nominal design discharge.

Table IV.19 presents the results of an analysis of' the intensity of operations at the two diversions Branch Canal 2 and Distributary Canal 5 along the Kirindi Oya Right Bank Main Canal. The intensity of operations is expressed in terms of the daily mean number of interventions at the structures of the two diversion locations over certain periods of time.

The table indicates that the frequency of this type of operations at the cross-regulators varies widely in time and in space along the main canal; it shows that the operations are in general more frequent in the lower reaches of the main canal compared to the upper reaches. A peak was reached from 6 March to 10 April 1988 at GR12:BC2[4] with an average of more than five gate operations per day at the cross-regulator whereas there was less than one operation at GR3:DC5[5] for the same period.

This reflects the increasing difficulties faced by the operators to maintain an appropriate head in the lower portion of the main canal (Tract 5) during situations of high irrigation demand whilst at the same time delivering water in the upper reaches. In other words, it highlights the magnitude of the disturbances caused to the regime of flow downstream by the current operational practices in the upper reaches of the system.

<u>Second type of operations</u>: less frequent than the first type. The gates at the offtakes of the lateral canal are operated. Operations are done either in conjunction with the operations of cross-regulators or separately.

At Distributary Canal 5 in Tract '1, during the previous irrigation season, temporary closures of this canal. have been recorded regularly from 18 March. until the end of the irrigation issues in Tract 1 and final closure of Distributary Canal 5 on 7 April 1988. The gate openings at this location between 20 and 27 March 1988 shown in Figure IV.49 are an example. These offtake closures were generally not associated with adjustment at the cross-regulator unless the difference in water level between the main canal and at the head of the distributary canal became too small and prompted remedial action at the cross-regulator gates (partial closure) to restore the flow diverted. Paradoxically, the adjustments performed in response to such situations, usually created owing to a reduction of inflow in the main canal, sometimes led to an increased diversion of water.

At Branch Canal 2 in Tract '5, the operations of that gate in relation with the gated cross-regulator GR12 have been more comples because of the dual function of this canal during this particular season. In addition to the supply of the area under its command, the branch canal was also used as a drainage channel to evacuate excess water concentrating in the lower portion of the Right Bank Main Canal. This latter function was resorted to whenever necessary 'to protect a temporary coffer dam located below gated cross-regulator GR15, five kilometers downstream of Branch Canal 2. This coffer dam, built by the Irrigation Department, has been in place for the whole season (although several times breached and rebuilt). It was intended to prevent water flowing beyond Tract 5, thus minimizing operational losses. It also served to impound water in the last reach thereby increasing the water surface elevation and facilitating the water supply to the lateral canals located in this reach.

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[4]This denotes the study location that includes the gated cross-regulator GR#12 and Branch Canal-2.

[5]This denotes the study location that includes the gated cross-regulator GR#3 and Distributary Canal-5.

The presence of the coffer dam, and the particular concern of the field irrigators to ensure its protection has played an important role in the operation of the lower portion of the main canal. Some informal mode of regulation seems to have been practiced by the irrigators; information regarding the status of water at the coffer dam was communicated to the irrigator in charge of GR12:BC2 so that preventive action. consisting of diverting the excess water through this canal could be implemented. Such a discharge of escess flow through the branch **canal** was recorded on 10, 13, 23, and 28 March 1988. This was achieved by fully closing the gated cross-regulator GR12 while opening the branch-canal offtake. The episode of 27 to 28 March 1988 is fully described in Annex IV.3.

The reverse type of operation at GR12:BC2 (i.e., closure of the branch canal to release additional water to the tail) was also observed. For example, on 8 May 1988 the gate of the branch canal was closed following a big reduction of inflow at the head of main canal. The events that led to this closure were as follows:.since 6 May the irrigator had been making a number of interventions to progressively close the gates of GR12 so that full supply depth could be maintained at the cross-regulator. The flow released to the tail also decreased, up to the point that the branch canal had' to be fully closed on 8 May to release sufficient water to the tail end. This sequence of events is shown in Figure **IV.50.**

<u>Other types of operations</u>: in exceptional circumstances. Yet another option was implemented in Branch Canal 2 to reduce the **flow** into it at a time when it was not possible to operate the offtake gate for a few days. This was achieved by changing the hydraulic conditions downstream of the offtake gate. It. has been observed that all interested parties (field irrigators and farmers) are well aware of the potential impact of backwater on **flow** into the branch canal, and they apparently know how to "manipulate" it when necessary.

This unexpected situation arises not only because of the gentle topography of the command area served by the Right Bank Main Canal,' but also for various reasons pertaining to the design and construction of the system. Thus, the difference in elevation between the outlet of the offtakes and the canal bed of the lateral is3 often not sufficient. These conditions are aggravated if for some reason, canals are not excavated to the design level !construction flaw), or when the design also includes the location of structures (i.e., checkgate, culvert, etc.) downstream of the offtake, the operation of which could interfere with the functioning of the offtake !design flaw), or when siltation of the lateral canal raises the bed level (maintenance flaw).

The design does not always provide permanent free-flow canal sections below the offtakes such as drop structure (i.e., a "hydraulic control") that would decouple the hydraulics of the lateral canal from that of the main canal. This means that operation of a check structure in a lateral can affect the flow diverted into the lateral, and hence the flow in the main canal itself. Owing to the absence of free-flow conditions at the offtakes, the identification of rational operations of a system and determination of correct settings of the various adjustable structures constitute fairly complex tasks, beyond the current capacities of the operators. These hydraulic complesities are at the origin of the difficulties experienced by the operators to control the delivery.

In the case of Branch Canal 2, a drop structure exists abut 100 meters downstream of the offtake. One distributary canal and one field channel are located in-between the offtake and the drop structure. The drop Structure is fitted with a gate, the assumed function of which is to provide more flexibility in the supply of the lateral canals at the head of Branch Canal 2. On 26 April 1988, the flow diverted into the branch canal was too much, but operations of GR12 and the gate of the Branch Canal 2 were temporarily impossible because of an on-going water measurement campaign at that time. According to the records, the' checkgate in Branch Canal 2 was partially closed at, midnight either by the field irrigator or the farmers. The backwater effect was propagated upwards, reducing the effective hydraulic head over the offtake gate orifice and resulting in a reduction of about '14 percent of the flow diverted into the branch canal. This setting apparently remained unchanged for several clays until the gate at the drop structure was finally lifted around 10 May 1988, hence changing again the hydraulic conditions downstream of the offtake (see Annex IV.2).

<u>Preliminary conclusions</u>. The design of the Kirindi Oya Right Bank Main Canal provides the field irrigators with a very high degree of flexibility in terms of operational opportunities for achieving required diversions of water off the main canal. At many places, however, these operational opportunities are greatly underutilized, resulting in a certain redundancy, at least at the present time, when most of the gates are still in working order.

Consequently, the potential for combined operations of a multiplicity of gates at each diversion point renders the hydraulics of the main system very complex, especially when functioning under unsteady flow conditions which represent the commonly prevalent; situation. Up to five gates at a cross-regulator plus one gate at an offtake could interact in determining the flow to be diverted into a lateral. Not to mention the influence of the variation of inflow in the main canal (that could result from the operation of a regulator upstream) and the backwater effect (that could result from the operation of a regulator downstream). This situation is sometimes further aggravated by the interventions at structures located in the lateral itself, downstream of the offtake, that might also affect the flow diverted.

In 'contrast to the potential for a variety of complex operations provided by the design, the standing order of the agency, which is to maintain full supply depth at the regulator appears excessively simple. The decisions regarding the proper combination of structures to be operated and their respective settings are left to the field irrigator's judgement, based on his understanding of the system. The design values of full supply depth [corresponding to the crest of the side-walls of the cross regulators) do not always appear to be adequate in the eyes of the irrigators in order to divert the intended flow. The field irrigators have thus developed rather simplistic operational practices, based on their own experience, to ensure the supply of water to the laterals with the least effort on their part.

From the field irrigators' perspective, it appears that the cross-regulator has emerged as the privileged instrument of intervention to control the flow diverted at the offtake, which is their primary concern. The irrigators operate these structures intensively while paying little attention to the consequences of these interventions downstream and upstream of their locations (i.e., the sudden transfer, or storage, of water generated as a result of their interventions). Such interventions are an important source of variability. These aspects will be discussed in Section 4.3.

Kalankuttiya Branch Canal

The facilities available tc control the distribution are limited to the 20 offtakes existing along the 10.9-km branch canal. All offtakes have a gate except the last one at the tail (307-D3), which also acts as a drain for the branch canal. Although the system was first commissioned in 1978, the gates at the offtakes are still in working condition, the spindles are greased to ease the operations, and some of them even have a padlock.

<u>Regulated diversions</u>. Operations are performed by the two irrigation laborers in the course of their daily turn of duty along the branch canal. The irrigation laborer compares the water level in the weir-box at the heads of the distributary canals with the target (generally a standard depth of water at the hump-gauge) and proceeds with gate adjustments wherever necessary.

This appears to be straightforward, at least where there is an operational measuring device, but a detailed analysis of the reliability of the assessment of flow through these devices (as discussed in Chapter III) raised some questions in this regard. This might explain why the irrigation laborer does not always trust the gauge and tends to override the target if necessary to meet the farmers' demands (Raby and Merrey 1989).

Two-thirds of the distributary canals, however, are located close to duckbill weirs which regulate effectively the water level in the branch canal. Under these conditions, the frequency of offtake date adjustments has been found to be relatively low, provided that the pipe outlet of the offtake is not affected by a backwater effect.

The above observation is. supported by the results given in Table IV.20 which indicates the intensity of operations performed during the period May to September 1988 at the oi'ftakes 305-D3 and 308-D2. Both offtakes are adjacent. to the first duckbill weir and benefit identically from its water level regulating effect, but the offtake 308-D2 was subject to backwater effect and submergence while 305-D3 was not. The measuring weir at the head of 308-D2 was submerged and not operational during yala 1988 because of the partial closure of distributary canals downstream; only a portion. of the total command area was cultivated as part of the traditional <u>bethma</u> (or sharecropping) practiced during the dry season in Sri Lanka.

Table IV.20. Kalankuttiya Branch Canal: Frequency of interventions at two identically regulated diversions from 9 May 1988 to 10 September 1988.

Period	Number of interventions 305-D3	Number of interventions 308-D2
During rotational issues 161 days):	34.00	62.00
Daily mean:	0.56	1.02
Outside periods of issue (64 days):	13.00	20.00
Daily mean:	0.20	0.31
Considered as illegal during the whole period I125 days):	15.00	28.00
Daily mean:	0.12	0.22

Source: Datalonner record and f teld observations.

The above values indicate that:

a) more operations were performed at 308-D2 which is the offtake affected by the backwater effect; and

b) there were a substantial number of interventions (at both canal offtakes) performed outside the periods of water issue with a view to drawing off the water stored by the weir and partly refilled by the leak through the main sluice gates at the Kalankuttiya tank.

Nonregulated diversions. These are essentially the three offtakes located at the tail (307-D1, 307-D2, and 307-D3 the drain), two offtakes at the head of the canal (305-D1 and 308-D1), and two other offtakes located too far to be influenced by the duckbill weir immediately downstream (305-D2 and 305-D4). More interventions could be expected at the gates of these offtalies due to their relatively "unregulated" locations with respect to the duckbill weirs which make them more sensitive to water level variations in the parent canal (see also Figures II.14 and II.15).

Although it ha5 not. been the case during the period of this study, a special water issue is usually made to the two offtakes at the head (305-D1 and 308-D1), different from the ,rotation catering to the other offtakes. This special issue used to be implemented in conjunction with the closure of the gated regulator located immediately downstream of these canals.

Preliminary conclusions. Water issues to the offtakes can only be controlled by adjustments to 'the cates of the offtalies. Though the operational flexibility and the opportunities for influencing water issues are limited to a minimum, control of water issues nevertheless appears to be very effective. This is due to the fact that the majority of the distributary canals benefit frcm effective control of water level in the parent canal and that all the offtake gates are still in working condition after more than 10 years of operation.

Santo Domingo Area (SDA) Main Canal

The design of the diversion structures taking off the SDA Main Canal into the 11 major laterals are basically the same gated cross-regulating structures as those at Kirindi Oya, described above. There are. however, important differences' in the mode of operations of these structures. In addition to these, the main canal includes 35 "checks" or "thresher crossings" to allow for the diversion of water to a number of turnouts spread along the main canal.

Major diversions. Diverting a given quantity of water requires adjustments of a cross-regulator with multiple gates and an offtake with one or two gates. But. these structures are in a critical state of disrepair. In particular, the concrete anchoring of the cross-regulator gates to the body of the regulator were broken. It was reported that one reason for this damage was the illegal interventions of some people who close the regulators fully. But obviously there are flaws in the design and/or construction of the civil works which have been unable to resist the force deployed by the lifting mechanism. At the 11 cross-regulators, only 10 gates out of a total of 23 presently exist, but only 6 gates can be operated and that too with some practical difficulties. "it the offtakes, only 7 gates out of 13 can be operated but this does not seem to hamper the gate-keepers in their present, mode of operations.

Irrespective of whether a gate is present at the offtake, (e.g., Lateral B), or absent, (e.g., Lateral A), the current practice of the gatekeeper is to operate the cross-regulator and not the gate of the offtake to control the flow in the lateral. Thus, the control of the water issue is not direct but is by the control of water depth in the main canal. Some gates at the cross-regulator will be fully opened in order to curtail the issue of water to the lateral. Other offtakes located upstream (at least up to the next "check") will be thereby similarly affected.

This practice has been observed in detail at the Main Canal/Lateral B diversion during 1988. It has already been indicated in this paper that the gatekeeper was able to divide the incoming flow between Lateral B and the main canal downstream of Lateral B in nearly the same proportion as the ratio between the planted areas commanded by each canal; Lateral B received 40.8 percent of the inflow over the three-month period of observations compared to its share of 10.6 percent of the area. This, indeed is a remarkable achievement considering the facilities available. It is doubtful, however, whether this diversion arrangement was initially designed with a view to proportional sharing of water, given the structural difficulties involved in attempting to do so.

Shutting off the flow in Lateral B by operating the regulator to lower the water level in the main canal, rather than closing the offtake gate, is possible because the sill of the offtake is located at a much higher level than the bed of the main canal. But the result of this arrangement is that the division of flow corresponding to a particular setting of the regulator gates is extremely sensitive to the variations of level in the main canal.

In particular, Lateral B will tend to draw off more water than its share when flow increases in the main canal and less when main canal flow is decreasing.

The water level in the main canal varies widely due to the unregulated inflow and frequent gate adjustments are required in order to maintain the division of flow as per the intended proportion. The record of the gate interventions for the period from 24-31 July 1988 (Table IV.9 and Figure IV.26) and analysis of the division. of flow before and after intervention demonstrate the. ability of the operator to manage these conditions and determine the appropriate gate openings or closures to finally arrive at a fairly acceptable overall result in terms of the division of water at that point.

On the other hand it is likely that the frequent and important variations of the water level observed in the canal have a detrimental effect on the stability of the canal banks - depth variations of 1.5 meters/day have been observed and variations; of more than 0.5 meters/day were frequent-causing problems of erosion. This is aggravated by the current operational practices, especially when rotations between laterals are implemented.

Ninor diversions. Other types of structure are used for the diversion of water at the various turnouts located along the main canal. The design has provided "checks" (also known as "thresher crossings") at about 500-meter intervals across the main canal, single-gated turnouts, and double-gated turnouts of the Constant Head Orifice (CHO) type. There are presently 50 offtakes, plus 9 illegal pipe offtakes. Half of the turnouts installed are double-gated turnouts (CHO type) but none of them is operational. Only 25 percent of the total number of turnouts have a gate.

The "checks" are manually operated and do not have any gates. The water level is raised by placing or removing obstructions such as flashboards, banana trunks, etc. until the water head is considered to be adequate by the operators who are generally the farmers. Most checks are temporary but some are permanent. A great deal of farmers' activities is devoted to checking operations when water is short and also to their eventual removal under the instructions of the staff of the irrigation agency when flow is more abundant.

The operations of the "checks" may appear cumbersome and sometimes dangerous, but these are of primary importance to those "privileged" fanners who have direct access to the main canal water through the 59 existing offtakes. When the supply is short, however, these practices tend to favor farmers located at the head reach of the main canal at the expense of those located downstream.

Preliminary conclusions. The design of the SDA Main Canal has provided a significant potential for influencing water issues off the main canal. Cross-regulators and check structures have been provided along the main canal, at intervals of approximately 500 meters, and each offtake was initially provided with one or two gates. Yet, this potential cannot be fully exploited due to the poor physical condition of most of the control structures. Based on our observations, only about 25 percent of the regulator and offtake gates *can* be operated.

Irrespective of whether there is a gate at an offtake or not, water issues to the offtake tend to be controlled by the control of water level in the nwin canal, through the operation of the cross-regulator (at major diversions) or the check structure (in the case of minor diversions). Such interventions are performed with little consideration for their negative impact on the conveyance and distribution of water. In fact, the design configuration and associated mode of operation make it almost impossible to envisage the regulation of the conveyance of water along the SDA Main Canal.

Rajangana Pilot Area: Distributary Canal 1, Left Bank Tract 2

Issues of water to the laterals taking off from the pilot distributary .canalare made through the opening and closing of the three shutters of the baffle distributors which equip each of them. (The 30 liters/sec baffle distributors are composed of 3 shutters of 5, 10, and 15 liters/sec respectively, which can be manipulated separately to deliver any flow in steps of 5 liters/sec up to the maximum capacity.) Thus, the operation is straightforward for the operator as the shutters are precalibrated and do not need to be adjusted on a trial and error basis. They should be either fully closed or fully opened and the value of the flow delivered is indicated on each shutter.

Conclusions, with respect to Criterion C, of Section 4.2.2

The ability to influence diversions of water from the parent canal is determined by the means provided for this purpose by the design. Whether adjustable structures are maintained in working condition and whether their operations are convenient to the operators also determine the manageability of the system with respect to the control of water issues from main canals.

The canals studied displayed a variety of situations characterized by different degrees of flexibility of the design arrangements, which can be expressed in terms of the range of possible operational options left to the discretion of the operator at a branching point.

Amongst the four subsystems studied, maximum flexibility was observed along the Kirindi Oya Right Bank Main Canal. Here, an operator is presented with a large range of options for adjusting the flow diverted at an offtake. It can be either a direct operation of the gate at the offtake, an indirect operation at the rates of the cross-regulator immediately downstream, or a combination of direct and indirect operations. Such a situation was identified as having a high potential for complex hydraulics, hence difficult to manage, given the fact that the flow diverted at a diversion is not only affected by the operations of structures at that location, but also by the operations of structures located either upstream of that diversion (variation of flow resulting from the operation of cross regulators in particular), or even downstream through the effect of the backwater.

Similarly, the SDA Main Canal displays a very large operational flexibility. The initisl potential provided by the design, however, has been eroded by the current state of disrepair of the structures. The flexibility is still 'highbut operations are essentially of the indirect type.' The potential for complex hydraulics in the canal is extreme given the number of "checks" and the ad hoc nature of the checking performed.

Minimum operational flexibility was observed along the Kalankuttiya Branch Canal and along the Rajangana Pilot Distributary Canal. In these subsystems an operator is provided with a single and direct operational option (i.e., the operation of the gate or the shutter at the offtake). In addition to this, the impact of the variations of flow associated with operations of structures upstream tends to be minimized by appropriate design arrangements (duckbill weir), while the impact of downstream intervention is totally eliminated. The simpler canal hydraulics and the single operational option were identified as being favorable and more 'conducive to the rational operations of the offtake in achieving control of the water issues along the canals.

From this comparison it was observed that operators faced with a great deal of operational flexibility and complex hydraulics cope with such situations by means of over simplifications; the indirect type of operations focused at the cross-regulating structures are preferred for influencing'the flow diverted. On the other hand, flexibility limited to a single operational option at an offtake has not been identified as a constraint but rather as an advantage in achieving the objective of control of the water issues along canals, enhancing the manageability of systems while dramatically reducing the work load of operators.

4.3 REGULATION OF THE CONVEYANCE FUNCTION

4.3.1 Introduction

The different conditions necessary for the control of water issues by an operator, at the head and along main canals, have been discussed in Section 4.2. These conditions, though necessary, are not sufficient to ensure the control of water issues. In addition to the above conditions, water should also be available with an adequate hydraulic head at the point of delivery during the period of water issue.

Managing the transfer of water -'theregulation of the conveyance - aims to satisfy this particular type of requirement: the control of water levels. This includes both the control of water levels in intermediate tanks as well as the control of water surface profiles along canal reaches. But what is important to realize is that below the water surface there is a volume of water. Two typical water surface profiles along a canal shown in Figure IV.51 illustrate this point.

Along a canal equipped with cross-regulating structures, the reaches between the regulating structures could be viewed as a cascade of small storage capacities. This becomes apparent when the longitudinal sections of the canals studied are viewed (Figure II.9). As real canal systems have to be operated in a dynamic way, the volume of water stored in the various reaches varies with time. Therefore the filling/emptying of these storage capacities is a process which has to be properly managed if control of the water surface profiles along canal reaches and in reservoirs is to be achieved.

Three aspects of the canal regulation should be pointed out. They relate to the particular nature of the physical process corresponding to the transfer of water through irrigation main systems. These are:

1) Volume: the role of storage capacities. In a main canal which consists of a cascade of elementary storage[6] capacities, the possibility to refill a reach depends upon the availability of water that can be drawn off from the upstream reaches. Under the general regulation practices, this water represents what is left over from the upper reaches after eventual compensation for volume variation arising from a) man-made level adjustments through the operations of adjustable cross regulators, if any, and from b) natural variation of the water surface profile along canal owing to variation in flow (Figure IV.51).

This situation implies that an extensive cascade of interdependent storage is a constraint. In the process, any response to either a positive or negative water transfer will be delayed. This brings up two new elements of performance to be considered with respect to the management of a conveyance system:

* the responsiveness of the operations, expressed by the lag-time required to effectuate the transfer of a given quantity of water from head to tail (i.e., a measure of the inertia of the system); and

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[6]As indicated in Chapter II, flow along main canals is often subcritical as water surface in a canal reach is often raised above the critical depth through the operation of check structures located at the downstream ehd of reach. This creates opportunities for building up storage of water in a canal reach.

On the other hand, critical flow (or even supercritical flow) may exist locally for some distance downstream of "control" structures either natural or built in the canal design. Under these hydraulic conditions, a head-discharge relationship exists which depends on the physical characteristics of the control section. The water stored under the surface is also more limited and it is nil when there is no flow.

* the effectiveness of the operations expressed by the proportion of the additional water introduced at the head of the system that will eventually reach the tail (i.e., a measure of the conveyance efficiency).'

A number of techniques have been developed to alleviate these difficulties and improve the responsiveness and the effectiveness of the conveyance of water. These techniques are in the realm of planning and design, control technology, and improved operations of existing regulating structures. Some of them are reviewed in the course of the present comparative analysis.

For instance the judicious provision of intermediate storage capacities in a design increases the potential for more responsive operations with simpler regulation procedures. Intermediate storage permits to break the excessively long chain of dependencies quoted above. With appropriate management, intermediate storage can be made to act as a buffer capacity. These permit to decouple extensive systems into smaller subsystems which gain a degree of freedom for their operations at the head whilst neutralizing the variability originating from the upper system.

Therefore intermediate storage capacities have the potential, subject to them being appropriately regulated, to increase the overall manageability of irrigation systems. Water levels in intermediate storage tanks are the key parameters to be used for the regulation of water transfers in such main systems.

On the contrary, intermediate storage capacities which are inadequately managed might have an adverse impact on the responsiveness and manageability of systems. This situation exists in the operation of single bank canals.

2) Distance and time: the role of communications. In the preceding section, the control of a water issue has been analyzed as a local process handled by a low-level manager - the operator - who can normally get feedback on the spot regarding the consequences of his intervention on the flow diverted.

The regulation of the water transfer, on the contrary, is a time-dependent process that applies to a main system or main canal considered as a whole. Thus the distance and the time are the two essential dimensions which have to be considered by an operations manager responsible **for** the regulation process.

"Typically, the transfer of additional water at the head of a main canal is implemented by increasing the discharge which itself prompts the raising of the water surface profiles along the canal reaches even though the level would be maintained at **full** supply depth at the downstream end, either through hydraulic "controls," automatic control, or through the manual operations of the cross-regulators. Offtakes located along a reach are therefore likely to **take** more water, in proportion to the increased head, unless gate adjustments can be made in a timely manner.

Therefore, the availability of means of communications whereby an operations manager can obtain feedback regarding the on-going processes at remote locations, and communicate operational instructions, are central aspects of the regulation of extensive main canals and main systems.

Information must be available in a timely manner if it is to be of any use for the canal regulation. Therefore, the feedback should be selective and should focus on key parameters and locations such as the tail-end section of a main canal, the boundary of operational units, the head of major diversions. escape structures, etc.

The response time considered as appropriate for the communication process (in reality feedback plus response time) is a variable which depends, to some extent, on the inertia of the physical process. For instance the weekly meeting of the System H Water Management Panel at Galnewa, which reviews the status of intermediate storage capacities and sets new conveyance targets for the week, might still be adequate for the regulation in that particular case given the available buffer capacity of the tanks.

3) Process: The initiation of water transfer. Although water always flows from head to tail, the transfer of water through a canal can be initiated from one or the other end of a canal reach: either filling or draining. Similarly, within a series of canal reaches, with or without intermediate reservoirs, it is important to distinguish whether the transfer of water will be effectuated from reach to reach starting from the head end and "pushed" downward to the tail of the system or, alternatively, in the reverse order with the mobilization of downstream storage capacities first, which are subsequently refilled from the adjacent reach upstream.

In this study the first process is called an upstream mode of regulation while the second a downstream mode of regulation. This distinction is important because of its implications on the communication of operational information which would have to be consistent with the particular mode of regulation.

The upstream mode is most favored for the operation of distribution systems characterized by control of the water issued at the head of a main canal and then propagated downward from reach to reach. It is not uncommon, however, to observe changes which originate at the downstream end (the offtake) in response to fanner demand (e.g., Kirindi Oya Right Bank Main Canal).

The downstream mode is likely to be confined to the operation of main systems in the absence of adequate control of delivery. For instance this would be the mode of operation of a conveyance system permitting to refill intermediate tanks when necessary (e.g., transfer from Kalawewa Tank to Kalankuttiya Tank).

In this chapter, the canals studied are used to illustrate a) some of the approaches applicable to the control of water level in canals as laid down through the planning and design stage; and b) the implications of these in view of the necessary regulation of the volumes of water in transit from canal reach to canal reach including intermediate storage tanks, throughout the main system.

In an attempt to assess the manageability of the systems studied with respect to the regulation of the water conveyance, the four specific criteria, listed in Section 4.1, have been used as follows:[8]

Criterion D: Availability of operational targets for the conveyance of water

The availability of targets is a prerequisite for any control process. Conveyance targets might take the operational form of a given volume of water to be transferred from tank to tank and monitored either by the variation of level in a reservoir or by the assessment of inflow and outflow for a certain period of time or by a combination of both. Along canals, the transfer of water is often constrained by the other conditions set for the control of the water issues. This is usually translated into operating rules which state that the transfer of water has to be effectuated from reach to reach while maintaining the water surface at full supply depth within each reach.[9]

Criterion E: Availability of means to store and release water within the main system and to control water level at key locations along the main canal

The availability of some form of intermediate storage capacity within a system is of paramount importance for the regulation of the water transfers. If such a storage is allowed to fluctuate, it can provide a buffer capacity between two subsystems, hence an opportunity for the two subsystems to be regulated separately to some extent. Intermediate reservoirs do not always exist in main canals but some limited storage capacities might be built in the canal itself, either through the provision of cross-regulating structures or in storage adjacent to main canals.

Regarding the control of water levels, three different approaches have been identified in the canals studied:

1) Manual operations of adjustable cross regulating structures. The provision of cross-regulators with undershot gates is the most common technique used in irrigation canals to tentatively control water level

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[8]These criteria are referred to as Criteria D, E, F, and G to distinguish them from Criteria A, B, and C which have been employed in assessing the manageability of the systems with respect to the control of the distribution function.

[9]To achieve this means that a balance between inflow and outflow (including infiltration losses) has to be maintained in each reach at any one time. In a series of canal reaches separated by cross-regulating structures, this esercise is likely to be difficult to achieve if inflow is varying, unless special design or operational arrangements have been established to cope with this variability. The availability of such arrangements are examined in this section.

through manual operations. This was studied in the Santo Domingo Area (SDA) Main Canal and at the Kirindi Oya Right Bank Main Canal.

2) Design of fixed hydraulic "control" structures. The provision of hydraulic "controls" such as long-crested duckbill weirs makes it possible to maintain water level at the weir, and immediately upstream, within a narrow range irrespective of the flow variations in the main canal. This was studied at Kalankuttiya Branch Canal.

3) Iristallation of automatic level-control technology. The provision of hydromechanical gates like the one installed at the head of the Rajangana Pilot Distributary Canal permitted to automatically control the water level downstream of the gate as required for the operation of the main baffle distributor.

Criterion F: Availability of information regarding the status of water storage (or water level) in reservoirs (or main canals)

. Water transfers can be assessed through the variation of level in reservoirs with correction for possible water issues during that period. The depth-capacity curve of storage reservoirs permits to assess the variation of the volume stored by monitoring the tank water level.. Volumes issued can be obtained by integration of the flow delivered at the place of delivery over the time.

Along canals, the storage capacities corresponding to different water surface profiles for different steady flow conditions are generally not readily available to the irrigation agency in charge of operations. By default. the' current operating rules related to the management of the transfer of water do not take into account the variations of built-in canal storage capacities corresponding to the different flow regimes. Instead, the operating rules are generally expressed in simple terms to the operators (i.e., the standing order to maintain water level at full supply depth at the regulator). These rules mean that the volume of water contained within a reach would increase or decrease with the variation of inflow. This would to some extent. perturb and delay the transfer of water. Water surface profiles in reach GR12-GR13 of the Kirindi Oya Right Bank Main Canal with water level at GR13 maintained at full supply depth are given in Figure IV.41.

Criterion G: Availability of means for communicating the information required for the regulation of water transfers

Amongst means currently used for the communication of information in view of the canal regulation, the most common are: 1) the regular meetings of staff responsible for canal operations; 2) operators carrying messages over short distances using local transport, push bicycle, etc; 3) the use of telephone and radio communication system over long distances; 4) in some cases the transmission is done by the water itself (backwater). This hydraulic peculiarity is harnessed by hydromechanical technology such as the automatic gate used for the control of water level downstream of itself installed at the Rajangana Pilot Project..

4.3.2 Current Concerns and Practices of Agencies Regarding the Regulation of the Conveyance of Water in the Systems Studied.

Several aspects in the above respect have already been discussed in the preceding sections. Reference is made to in Chapters III and IV, and Section 4.2. in particular. Only the main observations are reviewed in this section in the light of the above criteria, in an attempt to evaluate the manageability of the systems studied with respect to the conveyance of water. A summary of this comparative evaluation is given in Table IV.21.

At the higher level of decision-making in agencies - the operational level concerned with the management of the water resource stored in the main reservoir - decisions are made regarding the allocation of water to the various reaches of main systems

Agencies determine at the onset of an irrigation season, the extent of area to be irrigated, and prepare an indicative seasonal plan that represents tentative allocations, of water planned on the basis of the most probable scenario of water resource availability and water demand anticipated for the area to be irrigated. Water level in the main storage reservoir used in conjunction with the depth-storage relationships are key elements for the decisions regarding water allocations (Figure III.12). In the Mahaweli System H, the Seasonal Operating Plan (SOP) approved by the Water Management Panel at the office of the Mahaweli Authority of Sri Lanka in Colombo serves that function. Its elaboration is more complex because of other considerations, particularly the priority attached to the production of hydropower. A similar plan is elaborated at the project office of the Upper Pampanga River Integrated Irrigation System, Cabanatuan, and by the Senior Irrigation Engineer, heading the Water Management Feedback Center, for the Kirindi Oya Irrigation and Settlement Project.

In the course of a season, the actual allocations and the decision-making that lead to these are quite different. As indicated in Chapter II, decisions often take place at a lower level within the administrative-managerial setup, either at the project level (Galnewa Project) or at the level of the subsystems (Kalankuttiya Branch Canal), or even at the level of the lateral from the main canal or the offtake (Kirindi Oya). These decision-making processes usually take into account the hydrological conditions at the time of the water issues as well as requests from farmers.

The fact that actual allocations tend to be decided upon at the intermediate operational levels while water resource management is dealt with at the highest level, implies that if the regulation is to be effective there should be communication between these levels and feedback provided to the higher operational level.

The schedule of intended water allocations, formulated through whatever decision-making process, forms the basis of what is referred to in this study as operational targets for the conveyance of water. The rationale for these processes and the adequacy of their outcomes - the targets - are not discussed in this section of the study. Instead, the aim of this section is to ascertain whether or not these decisions are made. If decisions are

Table IV.21 Regulation of conveyance systems

CRITERIA	MAHAWELI SYSTEM H		UPRIIS		KIRINDI OYA	RAJANGANA
	KALAWEWA LEFT BANK MAIN CANAL	KALANKUTTIYA BRANCH CANAL	DIVERSION CANAL DC#1	SDA MAIN CANAL	RIGHT BANK MAIN CANAL	PILOT DISTRIBUTARY CANAL
D. AVAILABILITY OF OPERATIONAL TARGETS (for the conveyance)	Yes	Yes	Yes but not explicit (inadequate for the regulation)	Not available (except at the head)	Yes (but implicit targets set by the Irrigation Laborers' intervention are sometimes inconsistent with SIE's target at the head)	Yes (but not explicit at the tail)
- form of the targets:	Schedule of daily inflow/outflow and anticipated water level at each intermediate tank.	Schedule of water issues at the Kalankuttiya tank main sluice Target for the tail (307-D3) coincides with distribution target.	Target flow at key branching points but no schedule of the volume to be transferred. No rules for operating regulators	No conveyance target along SDA but only division of inflow Expected flow at head of SDA not explicit.	Control of water issue at the head, plus standing order along RBMC (to maintain FSD at the regulators)	Control of water issue at the head.
- formulated by:	Prepared by the IE, LBMC Unit on the basis of requests placed by the IEs of the blocks following decisions of the Water Management Coordinating Panel, Galnewa.	The Irrigation Engineer (IE), Galnewa Block	The WCCC in consultation with the District Hydrologist	The Hydrologist of District I	SIE/Water Management Feedback Center at the head; and also by the Irrigation Laborers' at the offtakes.	Technical Assistant of the Irrigation Department.
E AVAILABILITY OF MEANS FOR STORAGE AND FOR THE CONTROL OF WATER LEVEL ALONG CANAL	Yes, several intermediate tank & opportunities for manual control of level	No intermediate storage but effective control of level (duckbill weirs)	No intermediate storage limited opportunities for manual control of level	No intermediate storage Multiple opportunities for manual control of level	No intermediate storage Good opportunities for manual control of level	› intermediate storage but ffective control of level
- intermediate storage capacities	Mulannatuwa, Kalankuttiya intermediate tanks	Storage built in the canal cannot be mobilized for the regulation	Limited to the storage built-in the reaches of the diversion canal.	Limited to the storage built-in the canal at the many "checks" and cross-regulators.	Storage built-in the canal reaches cannot be mobilized under the current rule of operation (FSD).	storage
- control of level along main canal	Through the operations on gated cross-regulators	Through duckbill weirs	Through a few radial gates	Through gated cross-regulators and a large number of "checks"	Through gated cross-regulators	ough duckbill weirs
F AVAILABILITY OF INFORMATION REGARDING WATER LEVEL/STORAGE	Only tank level available to the IE, LBMC Unit	Only at the head of BC (but level at the tail of BC not available to the IE, Galnewa)	Not available to the WCCC	Not available to the Zone Engineer	Not available to the Resident Engineer-Right Bank (RE-RB)	Not available
- tank water level	Level-storage relationship exist and tank level monitored by LBMC Unit	na	na	na	na	na
- canal water level	Not available (except at the ganging station of the FMU)	Water level at the tail of the BC not available to the IE, Galnewa	Level/storage not available to the WCCC nor to the District Operation Engineer.	Level/checking along SDA not available to the Zone Engineer of the District	Level/storage in the various reaches not systematic and not available to RE-RB & SIE, Water Management Feedback Center	Volume delivered at the tail not available to the Technical Assistant.
G AVAILABILITY OF MEANS FOR COMMUNICATING INFORMATION	Weekly meeting of Water Management Panel	Field Note from Unit Manager to Irrigation Engineer	Radio communication system plus meeting	Visit of the Zone Engineer	Field inspection by SIE and mail	Field inspection
	Weekly meeting of the Panel plus personal communication through the IE, Flow Monitoring Unit. Communication between Galnewa and higher MASL through CIE, Colombo	From IEs through the Unit Manager; communication between head and tail of the canal become more difficult since its partition into 2 blocks.	Radio communication between WCCC, the District Hydrologist and Rital Ima Liaison officer along DC#1 Field inspection by WCCC	Regular visits to SDA by the Zone Engineer to meet the WNT; Office of the Zone Engineer at the District facilitates contact with Hydrologist.	Regular inspection by SIE along the RBMC and correspondence with the Resident Engineer of the RB Office. Patrol along canal by IE/RE-RB	Walking distance Irrigation Laborers' Report to the Technical Assistant.
MANAGEABILITY and associated MANAGEMENT EFFORT	Fair and Affordable	Fair and Easy	Poor and Different	Poor and Impossible	Fair and Difficult	Fair and Easy

found to be made, it is attempted to find out whether these decisions are operational so that they could serve as targets for the transfer of water and whether information and feedback is provided to the operation level which is in control of the water resource.

Mahaweli System H: Kalawewa Left Bank Main Canal and Kalankuttiya Branch Canal

During maha 1986-1987 the Mahaweli Economic Agency experienced a severe drought which strained the conveyance of water through the Mahaweli System H. Deficiencies observed at that time led the water level in the Kalankuttiya Tank to drop below its minimum operational level with subsequent loss of control over the distribution in that block. This situation pointed out the need for more effective regulation procedures for the transfer of water from the Bowatenna Diversion to Kalawewa Tank and to other intermediate tanks of the system.

Since then, the procedures followed by the Mahaweli Economic Agency for the regulation of the system were strengthened. The System H Water Management Coordination Panel created at the time of the crisis provided, through its weekly meetings, a forum for communications and feedback between various operational levels which proved to be effective.

The Kalawewa Left Bank Main Canal Unit, a new managerial level, was created in January 1988, to specifically oversee the operation of the Kalawewa Left Bank Main Canal from Kalawewa up to and including half of the Kalankuttiya Branch Canal. The new unit has not been fully operational in 1988 and its staff not yet entrusted with authority in accordance with the hierarchical position of the system managed. Yet, this Unit clearly filled a void in the previous operational setup of the agency.

1) Transfer from Kalawewa to Kalankuttiya Tank via Mulannatuwa Tank. On the basis of the resources available in the Kalawewa Tank, the System H Water Management Coordinating Panel reviews weekly the rates of water issue to be adopted by the Galnewa and Meegalewa irrigation engineers and for the formulation of their request to the engineering assistant heading the Main Canal Unit. The engineering assistant prepares a daily schedule of anticipated inflow and outflow to and from each intermediate tank as well as the water levels anticipated daily in the Mulannatuwa and Kalankuttiya tanks which should not be below three and five feet respectively (Criterion D). He uses for this purpose the depth-discharge relationship of the tanks (Table IV.22). These values are not necessarily used as targets for the actual operations and they do not provide a reliable record of the actual issues. These values do not tally with those more reliably assessed separately by the Flow Monitoring Chit on the same canals for the purpose of postseasonal evaluation.

The intermediate storage capacities available at Mulannatuwa and Kalankuttiya tanks (Criterion E), though limited in volume, play an important role as buffers, in the regulation of the main system. Kalankuttiya Tank for instance neutralizes the variability of the supply from Kalawewa while permitting to implement a schedule of rotational water issues downstream without being constrained by the supply.

The simultaneous delivery cf water from the left bank main canal between Kalawewa and Mulannatuwa tanks (16 distributary canals of the Galnewa Block), however, was reported to be a recurrent problem which affects the effectiveness of the transfer of water between those tanks. So far, the staff of the Mahaweli Economic Pgency have made various attempts to alleviate these difficulties through strengthening the supervision and control over these deliveries when water is short and scheduling the delivery to Galnewa either simultaneously while performing its conveyance function (yala 1988) or alternatingly (maha). But in any case, the irrigation engineer reported to the System H Water Management Coordinating Panel that he needed at least 5.7 liters per second (200 cusecs) in the left bank main canal for its operations with respect to the Galnewa Block.

The Flow Monitoring Unit has installed 12 measurement stations fitted with stage recorders between Kalawewa and Kalankuttiya. But this information is not. used by the staff of the Left Bank Main Canal Unit for the operations of the left bank canal. The operations staff, however, obtain a fringe benefit from this intensive monitoring activity in the sense that the staff get access to gauging sections with their corresponding rating curves (Criterion F).

During the drought of maha 1986-87, the shortfall in the expected augmentation of the Kalawewa Tank resource through the Polgolla-Bowatenna Diversion was a key issue. But the relative <u>uncertainty</u> attached to this augmentation has often been 'pointed out by the System H Water Management Coordinating Panel as being at the origin of the difficulties they have for planning the water allocations downstream. Amongst the constraints quoted are the limited capacity of the tunnel at the diversion, and the priority given to energy at the cost of agricultural use of the water. There is also an inadequate communication mechanism between the Galnewa Project level and the upper managerial level, the Mahaweli Authority of Sri Lanka (Raby and Merrey 1989).

In yala 1988, the water resource has been relatively abundant and the water received from Polgolla has not been a constraint. But it was reported that the targets recommended by the System H Water Management Coordinating Panel were not respected by the irrigation engineers resulting in more water being issued than planned.

2) <u>Transfer from the Kalankuttiya Tank downward</u>. In the case of the Kalankuttiya Branch Canal, the conveyance target set by the Irrigation Engineer, Galnewa, consists of defining the duration of the rotation and the flow to be issued from the tank (between 2 to 3 m3/sec) (Criterion D). The schedule is very flexible. For example, the starting date of the issue is decided upon with very little notice, the schedule permits to accommodate demands from the farmers for extension of the period of water issue which are generally satisfied within a day, and the canal is closed during the rain and the schedule is modified accordingly (Figure IV.8).

Irrigation laborers do not have to bother about the control of water level in the branch canal since a series of nine duckbill weirs perform this "automatically" provided that the flow released at the head is adequate for the water to flow over the nine duckbill weirs to the tail (Criterion E). But this supposes an adequate control of the delivery at the offtakes. The analysis made in Section 4.2 has shown that this condition was not always mot. As a result more water has to be issued at the head of the system to compensate.

This is a case whereby the control of water issues at the offtakes is the stumbling block for the regulation of the canal. But at the same time, the performance achieved in the control of the water level at the offtake might be conducive towards achieving this end.

Regarding the effectiveness of the water transfer, observations indicate that it is low after a canal closure until the canal gets refilled. For instance on 20 May 1988 the tail end farmers of Meegalewa made a request to the Irrigation Engineer, Galnewa, for an extension of the water issue so that they could complete the land preparation in that area. The request was accepted and the branch canal was reopened at 0800 h. For the period, 0800 h to 1600 h, 41,087 cubic meters of water were released from the dam, but the record indicates that only 5,551 cubic meters actually reached the tail (13 percent). The graphs in Figure IV.52 indicate the discharge in the branch canal at the head (data from stage recorder) and at the tail in 307-D3 and also the water level variation in the canal at Duckbill Weir-1 for 20 May 1988.

Between water issues, the irrigation laborers seem to have difficulties to keep the offtakes closed in the face of the pressing demand of farmers to draw upon the water accumulated behind the weirs, and the ponds soon get empty. Consequently, it takes about 12 hours to refill the canal at the start of the next water issue. A practical consequence of this is that water usually arrived late in the evening at the tail of the branch canal when farmers are no longer in the field to receive it. But on the contrary, the water at the tail end is shut off soon after a canal closure.

From the above observations, it appears that the tail (307-D3) is a key location from which feedback has to be communicated to the operator of the headworks in view of the regulation of the branch canal. It is interesting to note that the installation of a stage recorder at this particular location had been anticipated in the design of the canal and the shelter for it has even been built. A similar recorder has been installed at the head of the branch canal referred to as staff gauge MS1 in this study by the Flow Monitoring Unit for the purpose of evaluating the water issues released from the Kalankuttiya Tank over the season. The operator of the main sluice derives an incidental benefit from the calibration of this station to assess the tank water issue. But the envisaged recorder at the tail has never been installed. The agency does not monitor systematically the water conveyed at the tail of the branch canal as needed for the regulation. It has also no reliable means to assess the flow at the tail owing to the prevalent submergence of the measuring device at 307-D3 (Criterion F) (refer Section 4.2).

Furthermore, with the new organizational arrangement, the irrigation laborer who operates the offtakes in the tail portion of the branch canal during the period of issue, is now attached to the Meegalewa Block Office while the headgate operation is under the responsibility of the Main Canal Unit (it was actually under the Irrigation Engineer, Galnewa, during yala 1988). With respect to the regulation of the branch canal, dissociating operational responsibilities of the head from the tail appears as a drawback from the previous situation where both were under the Kalankuttiya Block. This is not conducive to facilitate communication and feedback from the tail to the head as needed for an effective regulation of the branch canal (Criterion G) even though systematic feedback was already lacking in the previous situation.

Upper Pampanga River Integrated Irrigation **System:** Diversion Canal DC#1 and Santo Domingo Area (SDA) Main Canal

1) Transfer through the Diversion Canal DC#1. The procedure used by the Water Central Coordinating Center to decide upon the flow diverted through the Diversion Canal DC#1 in consultation with the respective district hydrologists, has been presented in Chapter III and Section 4.2 in Chapter IV. It results in targets formulated in terms of discharge to be released or diverted at key locations within the system: at Pantabangan Dam, Rizal Diversion Dam, and Radial Gate RG#3 - the boundary between District II and District I - and at SDA Supply Headgate along DC#1. These last two points are of particular concern for the District I as the water has to first cross District II before entering District I (Figures 11.6, 11.7, and 11.8).

The targets used by the Water Central Coordinating Center for the conveyance of water through DC#1 are not expressed in terms of quantities of water to be transferred within a given period of time. Conveyance targets are not explicit and they do not seem to be recorded: intended discharge at the key branching points (including RG#3) and period of application (Criterion D). Thus, the flow monitoring performed does not appear geared to provide the timely information regarding the volumes being transferred as required for the regulation of DC#1 in a dynamic manner (Criterion F).

There is no intermediate storage along DC#1 except the storage built in the canal itself which is considerate and which can be varied through the operation of the radial gates (Criterion E). But there does not seem to be a systematic approach to manage the volume of water stored in the diversion canal and to monitor the water level with a view to regulating the water transfer. Instead there appears to be ad hoc practices like those observed in mid-September 1988 and reported in Annex III.1 and an alarming level of uncontrolled interventions on this major canal.

But the staff of the National Irrigation Administration do not seem to have a consistent approach to control of water level in DC#1, thereby in respect of the management of the water storage built in the canal. It is unlikely that this information is monitored and systematically communicated to the Water Central Coordinating Center (Criteria F and G). For example, the hydrologist of District I would at a given time decide to lower the water level upstream of Radial Gate #3 below full supply depth to prevent any illegal tapping of water upstream, or else, he will at certain times try to build up additional storage in the downstream reach of DC#1 to try to respond to the anticipated demand of the SDA.

The Water Central Coordinating Center makes use of a radio telecommunication system by which the district hydrologist can give some feedback on the status of the system and the Occurrence of rainfall in some part of the command area. This communication appears to be an essential link for the operation of the main system. It enables the highest managerial level to respond swiftly to any changing environment and take the appropriate action to conserve water from the Pantabangan Dam (Criterion G). This communication system is also used by the Center to inform the staff of the change in the targets to be used for the canal operation. The downward communication of information from the Center to the gate keepers along DC#1 and the implementation of the revised targets, however, do not appear to be working as efficiently as it is in the upward direction. From this observation, one may question whether the current targets and practices used for operations of DC#1 are appropriate from the point of view of the regulation of the conveyance of water along this diversion canal.

2) <u>Transfer from SDA Supply Headgate, on DC#1, downstream through SDA Main Canal</u>. As indicated in Section 4.2, the diversion of water from the diversion canal DC#1 is supposed to augment local flow available in the Sapang Kawayan Creek. It was also indicated that the National Irrigation Administration's source of information for assessing the local flow at this particular location was not adequate. This uncertainty together with the variability of both the local flow and the augmentation provided from DC#1 to the Creek, results in poorly regulated supply at the head of the SDA Main Canal (Figure IV.12).

The lack of any storage capacity at the head of the subsystem or along SDA Main Canal (Criteria E) does not provide a buffer against the variability of the flow, that could lead to improving the regulation and control of the water issues along SDA Main Canal. Furthermore, the multiple opportunities provided by the design for "checking" of the Main Canal make it almost impossible for the agency to envisage the management of the transfer of water from reach to reach whilst maintaining constant the head of water at the offtakes. Therefore, the SDA Main Canal seems to be operated under principles other than those of regulation and control of the water issues.

Owing to the absence of adequate regulation at the head of the subsystem, it was observed that the distribution of water amongst laterals had shifted towards a "degraded" objective: the achievement of equitable division of whatever flow that comes in.

But given these new water-distribution principles, one would question whether the design of the SDA Main Canal is the most appropriate. There is a large number of distributary canals taking off directly from the main canal and the design of the major diversion structures at the laterals using gated cross-regulators is particularly inconvenient for the proportional division of flow. But, this apparently <u>permits the agency to break free from the heavy constraints</u> which would be otherwise put on the management of the whole system if the objective was the control of water issues. Conditions such as the availability of delivery targets, assessment of flow 'against these targets, communication of information and feedback in real time for the regulation of the conveyance are therefore alleviated. Flow monitoring performed along SDA Main Canal is essentially an administrative task that has no bearing on the canal operations.

As a matter of fact, the current channel of communication that would eventually permit to satisfy a request for additional water placed by a water management technologist of the SDA is a long and hazardous process. At first, the technologist would consult his zone engineer during one of his regular visits and try to solve the problem at that level by a local reallocation. If insufficient, the zone engineer would take the matter up to the district hydrologist who will then contact the Water Central Coordinating Center. But in any case it would take more than three days for whatever additional water issue the Center might decide to allocate, to reach the SDA from Patanbangan Dam.

The criteria which have teen used so far in this analysis to assess and compare the manageability of a system do not seem to be relevant in the case of the SDA Main Canal which is currently not manageable according to these standards.

Kirindi Oya Right Bank Main Canal

Kirindi Oya Right Bank Main Canal represents a case similar to the SDA Main Canal in the sense that the distribution function of the canal is dominant and tends to mask the need to also manage the conveyance function. But while the National Irrigation Administration appears to have given up the intention to control delivery as per predetermined targets within SDA, this is still an objective at Kirindi Oya, at least for the Senior Irrigation Engineer of the Irrigation Department who oversees the operations of the Right Bank Main Canal at the project level.

The Kirindi Oya Right Bank Main Canal seems essentially perceived and operated as a distribution system and the targets used for its operations are not expressed in terms of dynamic transfer of a given quantity of water from the main reservoir to the different tracts of the system (Criterion D). Instead, the agency formulates targets in terms which actually describe a static hydraulic configuration of the canal, which the agency aims to achieve. It includes the following set: 1) the definition of the water to be issued at the main sluice in relation with the demand as perceived by the Senior Irrigation Officer of the Irrigation Department, 2) a standing order to maintain the water at full supply depth upstream of each regulator at all times, and 3) the concern to avoid water shortage at the .tail-end section of the main canal or excess flow which might endanger the coffer dam built by the agency to permit construction work further downstream.

On the other hand, the actual outflow of the system at the offtake is often left to the discretion of the irrigation laborers who manipulate the cross-regulators. By frequent and confused operation of the cross-regulators (i.e., storing or draining the cascade of ponds between the regulators), the irrigation Laborers generate pulses in the conveyance of water downstream which are detrimental to the regulation (Criterion E).

Water levels in the main canal are not monitored by the Irrigation agency though it is one of the stated operational targets (Criterion F). The volatile nature of this information which is affected by the operations of the regulators might be one of the reasons which preclude a systematic use of that information in the absence of adequate facilities to communicate and process meaningfully that information in real time.

On the other hand, should the agency wish to monitor the volume of water in transit at some section of the main canal, the assessment of flow would be particularly difficult, to achieve because of the submergence prevailing in all reaches. This would actually require individual assessment of flow through each bate of a cross-regulator plus, where applicable, the flow over the side-walls (Criterion E).

At Kirindi Oya Right Bank Main Canal, an assigned staff member systematically records the water depth at each offtake. Yet, for the reasons indicated in this chapter, including the limited reliability of that information, it is very unlikely that these records go beyond the files maintained in the office of the resident engineer.

More significant for the regulation of the canal is the first-hand information which the Senior Irrigation Engineer of the Water Management Feedback Center endeavors to obtain through his regular patrols along the main canal. Significant also are the nonofficial exchanges of information which the irrigation laborers assigned to the tail end of the canal seem to have developed 'to prevent the coffer dam from overtopping which would cause them to be fined. As reported in Annex IV.3, it was observed that irrigation laborers take remedial action in real time and divert excess water to the drainage through the Branch Canal 2. This was due to the lack of other means to communicate in real time this sort of information to higher decision-making level, the Resident Engineer Right Bank or the Senior Irrigation Engineer of the Irrigation Department for appropriate corrective action. Nevertheless, the coffer dam has apparently been breached six to 'seven times during the season despite the particular attention of the staff in that area and the financial incentive they have to protect it (Criterion G).

Obviously, the manageability of the system with respect to the conveyance of water is limited given the design of the existing regulating structures and the current mode of operation. An illustration of this is given by the diffusion from head to tail of the hydrogram representing an incremental release of water of 1.5 m3/sec for three hours on 2 May 1988 for the purpose of calibrating a mathematical model of, the canal. The record is obtained for an exceptional period without any intervention on the structures of the system (Figure IV.53).

Rajangana Left Bank Main Canal: Pilot Area

The technology and the design arrangements used for the pilot distributary canal have been presented in Chapter II and Section 4.2, Chapter IV. With respect to the conveyance of water through this subsystem the following points should be highlighted:

1) At the head of the pilot distributary canal. An automatic gate controls the water level downstream of it and thus, provides a downstream mode of regulation at the head of the system up to a baffle distributor installed next to it. From this point dorm, the system is supply driven. This particular arrangement permits to regulate the flow at the head of the subsystem in a way similar to what can be achieved at the main sluice of a intermediate tank (reduction of the variability).

2) Along the pilot distributary canal. The regulation at the head of the pilot area was a condition to envisage the extension of the regulation further dorm to the level of the field-channel turnouts. Design arrangements similar to those of the Kalankuttiya Branch Canal have been used for the control of water level at turnouts along the distributary canal.

The regulation of the conveyance through the distributary canal was expected to be simplified by the opportunity offered to the operator of the subsystem to easily check the correct balance between inflow (at the head) and outflow at the field-channel turnouts. Feedback from the tail was expected to be the key information needed by the operator for the regulation.

As indicated in Section 4.3, the potential of the above technology and design arrangement for a simple regulation of the system has not been fully utilized. The irony is that the expected advantage of the system with respect to the manageability of the regulation was annihilated through an intervention made at the tail for the purpose of flow monitoring.

4.3.3 Conclusions of Section 4.3

The analysis presented in Section 4.3 is an attempt to assess the manageability of the systems and main canals studied with respect to the regulation of the conveyance of water, if this were an objective of the irrigation agencies. At this point, however, it is necessary to put this assessment in perspective with respect to the present concerns of the operation staff and the current approaches of irrigation agencies in that domain. The following behavior were also identified in the course of the study.

* Irrigation agencies apparently share the concern to control the delivery of water from main canals but their approaches to the conveyance of water in those canals are not much elaborated. The perception of the need to manage this particular function in the eyes of the staff responsible for main canal operations is lacking. In addition, the awareness within irrigation agencies of the conditions - physical and organizational - which can either facilitate or complicate the effective management of the conveyance of water is very limited and this void has far-reaching consequences. These

consequences can be traced in the layout of main systems, in the design of the main canals studied, as well as in the organizational structure of the agency, especially in the setting of intermediate operational levels which does not necessarily match the Function of main canals, and finally in the managerial practices of those intermediate levels which often tend to hand off blindly to the operators all tasks related to the movement of water in canal, and implicitly the conveyance.

* The regulation of the conveyance of water does not seem to be a primary concern for the staff involved in the operations of the main canal studied. This concern, however, tends to emerge at the'higher operation-managerial level while the need arises to achieve more effective transfer of a scarce water resource from'tank to tank as in the case of the Kalawewa Left Bank Main Canal in the Mahaweli System H or through extensive conveyance system like the case of the diversion canal DC#1 at Upper Pampanga River Integrated Irrigation System. But despite this growing concern, the means and the efforts deployed by the staff who oversee the operation of canals of such a magnitude as DC#1, the practices were found to be ad hoc rather than to be rational and systematic, resulting in poor regulation of the supply of water at the head of the Santo Domingo Area (SDA) Main Canal for the period of the study.

* The standard approach of agencies with respect to the operations of main canals can be simplified as follow: 1) the flow in main canals should remain reasonably steady and the water level maintained at full supply depth so that the water issued at the head of main canal could be adequately delivered at the offtakes, 2) if necessary, it should be also possible to "push" the water downstream through the operation of regulators; these maneuvers are expected to be necessary to help the water to reach the tail of extensive length of canal faster. Under this approach the stream flow of water through a canal is viewed as a <u>static flow process</u> that is expected to be prevalent per contrast to occasional periods while it would be a <u>dynamic flow process</u> as a result of the pushing (or retaining) actions.

* With the above proposition (1), the regulation of the conveyance of water in the main canal is no longer a concern for the intermediate operational level which oversee the canal. This may justify why the main canal tends to be viewed (and designed) by agencies as distribution systems rather than conveyance systems.

* In an attempt to cope with proposition (2), agencies have evolved different arrangements by which the involvement of intermediate operational level is alleviated. Under the current approaches, most of the operations tasks, either control of the water issues at the offtake along main canal or occasional "pushing," are expected to be dealt with by gatekeepers with a minimum managerial input on the side of the higher decision-making levels. The intermediate operational levels tend to confine their role to the making of decisions regarding the water to be released at the head of subsystem and main canals. Eventually, and subject that they are in control of the water issues at the head of the canal (Kirindi Oya, Kalankuttiya), they may also involve themselves in formulating broadly what targets delivery at the offtake along main canal should be.

* Such operational arrangements were identified at Kirindi Oya for instance in the form of standing order given to the irrigation laborers in charge of the regulators (maintenance of full supply depth). For the SDA Main Canal, there is no order of any sort given to the gate keepers and the agency relies totally on their experience to deal with dynamic flow process. In many cases, however, the operational arrangements proposed by agencies to cope with the possible occurrence of dynamic flow process tends to increase dramatically the burden of the operators.

* In some other (rare) cases, arrangements have been made through the design to cope with dynamic flow process while relieving also the operators from the additional operation burden usually associated with these conditions. These arrangements were observed 'in the case of the Kalankuttiya Branch Canal and the Rajangana Pilot Distributary Canal with the provision of nonadjustable regulators .in the form of duckbill weirs.

* Because. intermediate operational levels lack the feel, the will, and eventually the know-how to manage the conveyance of water through main canal, the current flow monitoring performed by irrigation agencies is not geared to operations. On the contrary, the flow monitoring is generally perceived and carried out by operators who do it like another administrative burden required from them by the agency which they may eventually use for postseasonal evaluation of the staff. In each of the canals studied, there is scope for reconsidering the substance of the information communicated in view of the regulation of main canals, and the ways by which it is communicated to the level of decision making which are in a position to oversee the main canal.

CHAPTER V

IMPACT OF PLANNING AND DESIGN CHARACTERISTICS ON THE PERFORMANCE ACHIEVED AT THE LEVEL OF THE MAIN CANAL

5.1 INTRODUCTION

In Chapter IV, the necessity to control water surface profiles along main canals, and at the points of delivery in particular, has been emphasized as an important step towards ensuring the control of water issues. ***One*** objective **of** canal regulation is to achieve this effectively, either throueh management effort (e.g., operations of gated cross-regulators), or through design arrangements (e.g., duckbill weirs).

Therefore it is proposed, in the first part of the present chapter, to assess the performance of the regulation of the conveyance along the main canals studied in tenns of an indicator of the daily variability of water level at selected locations along the canals. The variability of flow observed at the offtake nearby will then be related to the recorded variability of water level in the main canal.

In the second part, the performance achieved is assessed in terms of the spatial variability of the water delivered at different locations along the main canals. The indicator used is the daily mean volume of water delivered per unit command area. This indicator permits a comparison of the water delivery, irrespective of the actual mode of distribution (either explicit flow control or proportional sharing), and gives indications of the equity of the distribution within the system.

The results obtained are evaluated with respect to the planning and design characteristics of each canal. The underlying causes for differences in performance are sought and comparisons are made across the different study sites.

5.2 VARIABILITY OF WATER LEVEL AT SELECTED LOCATIONS ALONG THE MAIN CANAL: IMPACT ON THE VARIABILITY OF FLOW DIVERTED

Kalankuttiya Branch Canal

The analysis will focus on two locations where intensive data collection was undertaken:

1) near the head of the branch canal, at the first duckbill weir, DBW1; the distributary canal in the immediate vicinity included in the analysis is 305-D3 (see Figure IV.29 for plan of data-logging station);

2) at the tail end of the branch canal; the distributary canal in the immediate vicinity included in the analysis is 307-D3.

Water level control at the two locations. Figure V.1 indicates the branch canal water levels recorded every 10 minutes by the dataloggers at these two locations during four typical rotations, two at the beginning of the season (23-26 May, and 31 May-3 June 1988, denoted R1 and R2 respectively), and two towards the end (19-22 August and 6-9 September 1988, denoted R11 and R12, respectively).

The water levels at the head and tail locations are plotted with respect to the pipe invert levels of the nearby offtakes 305-D3 and 307-D3, respectively, and thus represent the hydraulic head over these two offtakes, which, together with the offtake gate opening, determine the discharge into the offtake. Figure V.2 shows the discharges into these two distributary canals during the above mentioned rotations R1, R2, R11, and R12.

The daily ranee of branch canal water level variation at the two locations is shown in Figures V.3 and V.4, respectively. During the periods of water issue (generally 3 to 4 days), the daily range of variation in branch canal water level near the duckbill weir is extremely limited - the maximum, minimum and mean water levels nearly coincide with one another (Figure V.3). Extreme water levels occur more frequently outside the periods of issue. On the other hand, at the tail-end location considerable water level fluctuations are recorded both during and outside the periods of water issues. In fact the canal often runs dry outside the water issue periods (represented by the horizontal lines in Figure V.4).

The regulating effect of the duckbill weir at the head-end location is evident; the variation in water level during the periods of issue is negligible. The water level is maintained at around 10 centimeters (cm) above the crest of the duckbill weir. Significant variations in water level are only observed outside the cfficial periods of water issue when attempts are made to drain off the water retained by the duckbill weir. This water is supplemented by the leak out of the main sluice gates of Kalankuttiya Tank-the gates cannot be closed ccmpletely. On the other hand, the water levels at the tail end, which does not benefit from any form of water level control, exhibit large fluctuations during as well as outside the periods of water issue.

In the case of the relatively well-regulated 305-D3 offtake, the mean head is maintained at a reasonably constant value of approximately 1.1 meters whereas the unregulated 307-D3 offtake is subject to a mean head that varies between 0.3 and 0.5 meters. In fact the highest value of water level observed at the 305-D3 offtake at the beginning of the season, during the land-preparation period, was artificially induced when the water issue from the Kalankuttiya Tank was increased to facilitate flow measurements by the Flow Monitoring Unit of the Mahaweli Economic Agency.

In order to facilitate comparison between different locations the variability is expressed in nondimensional form in terms of the coefficient of variation (CV).

Daily coefficients of variation of branch canal water level at duckbill weir DBW1 and at the tail end are computed using the water level data gathered at 10-minute intervals by means of electronic dataloggers. The results are shown in Table V.l and Figure V.5 (duckbill weir DB#1) and Table V.2 and Figure V.6 (tail end). Variability of water level at DBWl is nearly zero during the water issue periods once a stable regime has been established. Some variations are present at the beginning (filling of canal reach) and end of the water issue periods, but these are essentially transient conditions that occur over limited durations. Stability is usuallv attained in 2-12 hours, depending on the magnitude of the flow in the branch canal and the offtake gate settinas. As expected, greater variation in water level is exhibited at the tail end.

Coefficients of variation of branch canal water level at the above two locations are also computed for each rotational period of water issue and are compared in Table V.3 and Figure V.7. The coefficient of variation of branch canal water levels near 305-D3 is relatively high during the period R2 because of the reduction in branch canal flow that took place during this rotation.. R11 also shows a slight increase in coefficient of variation as this was the period when the head sluice gate was rendered inoperable; the water flow out of Kalankuttiya Tank was thus uncontrolled, and varied with the drop in tank water level (see also Figure IV.7). Very low flow was maintained in the branch canal during R13, being the last rotation for the season. The branch canal water level also varied accordingly. However, the magnitude of variability at 305-D3 is practically negligible when compared to the variability recorded at the tail-end distributary canal 307-D3. (see Figure V.7.)

Impact of water level variation on discharge diverted at offtake. The coefficient of variation of discharge into the distributary canals 305-D3 and 307-D3 located at DBWl and the tail end, respectively, are computed for each rotational water issue period (Table V.4 and Figure V.8).

Given the low variability of hydraulic head. at the 305-D3 offtake compared to the 307-D3 offtake, the variability of discharge into the former offtake would also be expected to be correspondingly low. However, discharge variation is also influenced by gate operations at the 305-D3 offtake. This is well illustrated by the .relatively high values of coefficients of variation obtained for rotations R1, R2, and R12 during which operations of the 305-D3 offtake gate have been recorded. No gate operations were performed during the other :rotations and the coefficient of variation of discharge remained low.

In the case of 307-D3, the variability in branch canal water level is directly reflected in the variability of discharge in the distributary canal for the corresponding periods of water issue. Offtake gate interventions do not come into play as 307-D3 is kept open continuously so that it fulfills its function as a drainage channel for the Kalankuttiya subsystem. Figure V.9 indicates the extent of correlation between the coefficient of variation of branch canal water level and the coefficient of variation of distributary canal discharge during the different rotations. The only exception to the observed trend is R13, during which there was no flow at the tail end of Kalankuttiya branch canal for part of the rotation, thus accounting for the unusually high coefficient of discharge for this period. A discussion on the sensitivity of the discharge in distributary canal 307-D3 to water level variations in the branch canal is presented in Annex V.1.

In the case of 305-D3, on the other hand, the impact of the variability of branch canal water level on distributary canal discharge is not as clear cut as at 307-D3 (pee Figure V.10). The variations in branch canal water level at this location are themselves very small due to the presence of the duckbill weir. However, it will be noted that rotations R1, **R2**, and R12, during which gate interventions have been recorded at the 305-D3 offtake stand out from the other rotations when no gate interventions took place during the water issues. That is, although branch canal water level variability has been negligible, variations in discharge have occurred during R1, **R2**, and **R12** as a result of offtake gate operations.

Kirindi Oya Right Bank Main Canal

The analysis will be confined to the two monitoring locations on the right bank main canal consisting of a gated cross-regulator and associated offtake:

1) GR3:DC5 in Tract **1**, near the head of the system, **and**

2) GR12:BC2 in Tract **5**, near the tail of the system.

Daily range of water level variation. Figures V.ll and V.12 show that there is a significant daily range of water level variation above the offtake **pipe** invert at the two locations. However, little or no fluctuations were recorded at either location in the main canal between **26** April and 1 May 1988, when the whole right bank main canal system was maintained under the same steady state regime for carrying out the calibration of the right bank main canal mathematical flow simulation model. The impact of interventions at the head sluice, such as increasing and decreasing the main canal release, is felt to a greater extent at the head-end location (GR3:DC5) than at the tail (GR12:BC2). Examples are the increase in inflow on **2** May (for the model calibration under unsteady flow conditions) and the reduction in inflow on **6** May. A negative value indicates that the main canal water level fell below the level of the invert leve., of the offtake. Such situations occurred at GR3:DC5 on **22** March (when the GR3 cross-regulator gates were suddenly opened fully, presumably to send more water to the tail reaches) and again during the period of closure of the main canal between 11 and 17 April.

Another significant fact that emerges from Figures **V.ll** and **V.12** is that the mean operating head of the branch canal BC2 offtake (nearly **140** cm) is higher than the mean operating head of the distributary canal **Dc5** offtake (around **80** cm). This would a-priori be expected to result in a lower relative range of main canal water level variation at the BC2 offtake compared to that at the **Dc5** offtake.

Variability of water levels. Variability, expressed in terms of the daily coefficient of variation of main canal water level at the distributary canal DC5 and branch canal BC2, is shown in Figures **V.13** and V.14,

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considerably, by about 50 cm below FSD. The staff gauge in the creek indicated "32", rather close tc "36" - a level that corresponds to the target, discharre of 2.5 m^3/sec - and the hydrologist ordered the gatekeeper to make an adjustment. It looked as if someone had adjusted the gate according to the new target. Looking at IIMI's records logged in at 5-Bay SDA intake, such an adjustment might have taken place before midnight on 15 September. But at 0230 h on 16 September, the flow was already stepping down substantially, possibly because of the inflow interruption at RG#3 (see below), which prompted a drop of the water level in DC1 and reduced the flow diverted at the SDA Headgate. We also met the chief engineer of the WCCC doing an inspection and understood that he did frequent inspections in this area which he could conveniently visit because he lived there. He told us that he had already inspected DC1 early that morning and he reported a discharge at RG#3 of 6 m^3/sec. We proceeded along DC1 towards RG#3. The water in this canal was very low and DC1 was almost empty when reaching RG#3 - a situation which the hydrologist wanted to avoid through his policy of 70:30 (see p. 50). Someone had fully closed RG#3. This was possible as there was no lock to prevent unauthorized persons operating such a major structure. The gatekeeper, whose house was nearby, was not present. The water was rapidly building up in the canal upstream of RG#3 and it was about 15 cm above the maximum level as indicated by the red symbol painted on the canal bank; water was overtopping the radial gates and the hydrologist said that it would be risky to leave it as it was. Moreover, as he put it, he wanted to "get his water back." He explained that as far as he knew, District II had not requested water for the current period and therefore he was supposed to get for his District I the total flow of 5 m^3/sec of DC1. It was evident that he had no direct link with his counterpart but was reporting what he heard indirectly, possibly from the WCCC. After some initial hesitation, [the gatekeeper was still not present), the hydrologist decided to lift RG#3 gate by himself and we all helped him to do so. It took about 15 minutes to lift the only gate that could be operated, up to gradation "60". This was determined by the hydrologist on the spot using the UPRIIS/NIA Water Measurement Table and assuming a discharge rate and water head over the gate. Responding to our questions regarding target level to be maintained in the upstream reach as assumed for the gate setting, he said that he did not maintain the upstream reach of DC1 at RG#3 at Full Supply Level. He claimed that doing so would prevent District II from drawing water from the canal as they were not supposed to receive any water.

At this point the gatekeeper came back and explained that he had had to go to the town early morning. He insisted that the gate was opened when he left, and claimed that the farmers of District 2 were responsible for the intervention that occurred during his absence. When we questioned him on his role in canal operations since the rain on Wednesday, 14 September, he said that although he was aware of a reduction of the flow of DC1, he was still ignorant as to why this happened. He was actually expecting this information to be communicated to him earlier. He also reported that he met the Zone Engineer of District II to which District he was administratively attached, and that the latter had asked him to continue irrigating some upland farms that still needed water in the next District, although he normally received his instructions regarding the operation of RG#3 from the WCCC.

In this case, we can reasonably question the reliability of the gatekeeper's explanation about the timing and the circumstances in which the closing of RG#3 might have taken place. First, it takes hours to empty such a large canal up to the point which we observed on Friday morning. It is likely that, the closure happened during the night as IIMI's logger seems to imply. If so, RG#3's gatekeeper, if he had really left on Friday morning, should have noticed it. Another hypothesis is that if the water level maintained in the canal upstream of RG#3 was excessively low due to inappropriate setting of RG#3, the farmers of District II themselves would have been hindered from drawing any water from DC1. A third supporting hypothesis would be that the gatekeeper, as an employee of District 11, was persuaded to meet the demands of farmers in his District.

ANNEX 1112

List of Acronyms

LIST OF ACRONYMS

BC	:	Branch Canal
CEB	:	Ceylon Electricity Board
CRE	:	Chief Resident Engineer
DRPM(WM)	:	Deputy Resident Project Manager, Water Management
DC	:	Distributary Canal
DO	:	Dambulu Oya
EA	:	Engineering Assistant
FMU	:	Flow Monitoring Unit
HAOM	:	Headworks Administration and Operation and Maintenance
IL	:	Irrigation Laborer
ID	:	Irrigation Department
KYE	:	Kalawewa Yoda Ela
LBMC	:	Left Bank Main Canal
LB	:	Left Bank
NFAC	:	National Food and Agricultural Council
MEA	:	Mahaweli Economic Agency
MASL	:	Mahaweli Authority of Sri Lanka
MCU	:	Main Canal Unit
OE	:	Operations Engineer
PE	:	Project Engineer
RERB	:	Resident Engineer Right Bank
RB	:	Right Bank
SIE	:	Senior Irrigation Engineer
SHWP	:	System H Water Panel
TA	:	Technical Assistant
UM	:	Unit Manager
WCCC	:	Water Central Coordinating Center
WS	:	Works Supervisor
WMT	:	Water Management Technician
WMS	:	Water Management Secretariat

ANNEX IV.1

Background note to demonstrate impact of automatic downstream control gate and baffle distributor on control of water flows into the pilot distributary canal at Rajangana

Annex IV.1: Background note to demonstrate impact of automatic downstream control gate and baffle distributor on control of water flows into the pilot distributary canal at Rajangana.

(This note should be read in conjunction with the four accompanying figures.)

Observations

Period considered: 11-15 August 1988

	11/8	12/8	13/8	14/8	15/8
M/Sluice discharges (m^3/sec):	4.64	3.68	5.10	5.24	5.24
Rainfall at H/works (millimeters):	41	22	0	0	0

The variations in main canal water levels recorded by the datalogger at the heads of the Pilot and Control distributary canals (Figures 1 & 3) are due to:

- Rainfall on 11 and 12 August,
- Reduction in main canal flow between 11 and 12 August (4.64 --> 3.68 m^3/sec) in response to this rainfall, and
- Increase in main canal flow (3.68 --> 5.10 m^3/sec) in the afternoon of 13 August.

Computations

	PILOT (93.5 ha) (DC1, LB Tract2)	C O W L (147 ha) (DC2, LB Tract2)
Theoretical target discharges used by ID (on the basis of Water Management Consultant's computations)	159 liters/sec	263 liters/sec (i.e., 10.11 cm head over weir)
Corresponding volumes to be delivered over this 5-day period	68,688 m3 (735 m^3/ha)	113,616 m3 (773 m^3/ha)
"Modified" discharge target. apparently maintained as per ID's records for this period	200 liters/sec	390-400 liters/sec
Corresponding volumes to be delivered over this 5-day period	86,400 m3 (924 m^3/ha)	168,069 m3 (1,143 m^3/ha)
ID gate interventions recorded during this period	Nil	Nil
Actual discharges for this period as per IIMI datalogger records and rating curves	$194 \leq Q \leq 233$ liters/sec	$143 \leq Q \leq 392$ liters/sec
Corresponding volumes delivered over this 5-day period	93,128 m^3 (996 m^3/ha)	130,524 m^3 (888 m^3/ha)

Conclusions

1. The Irrigation Department (ID) appears to consistently maintain distributary canal flows at values superior to the theoretically computed targets; Possible reasons could be: incorrect assumptions in computation of requirements: response to farmer demands for more water; facilitating operations.

2. Discharges in the 'control' canal are more vulnerable to fluctuations in main canal water level; hence the need for more intense interventions at the offtake gate to respond effectively to these variations and maintain distributary canal flow at the target value. Otherwise, the distributary canal flows will also vary in response to main canal water level fluctuations and will differ from the target values, which is what actually happened during this period.

3. The combination of automatic gate and baffle distributor permits pilot canal discharge to be less influenced by water level variations in the main canal, i.e., discharge is maintained around 200 liters/sec without need for intervention on the part of agency staff. This demonstrates the relative ease of manageability of the hydromechanical devices installed at the head of the pilot canal compared to the classic undershot offtake gate at the head of the control canal. More effective control of discharge is thereby possible at the pilot canal.

4. Comparisons of targets versus actual volumes:

(a) with respect to the theoretical targets:

Pilot area - Actual delivery of 996 m^3/ha is <u>35.5 percent more</u> than the theoretical target of 735 m^3/ha.

Control area - Actual delivery of 888 m^3/ha is <u>14.9 percent more</u> than the theoretical target of 773 m^3/ha.

(b) with respect to the "modified" targets:

Pilot area - Actual delivery of 996 m^3/ha is <u>7.8 percent more</u> than the modified target of 924 m^3/ha.

Control area - Actual delivery of 888 m^3/ha is <u>22.3 percent less</u> than the modified target of 1,143 m^3/ha.

Comparison of actual deliveries against the so-called modified targets is more appropriate as these latter values more realistically represent the operational targets of the agency. The above results again demonstrate that delivery targets can be more effectively maintained at the head of the pilot canal compared to the control canal.

Figure 1 Comparison of water levels, pilot canal

11–15 August 1988, Rajangana (LBMC)

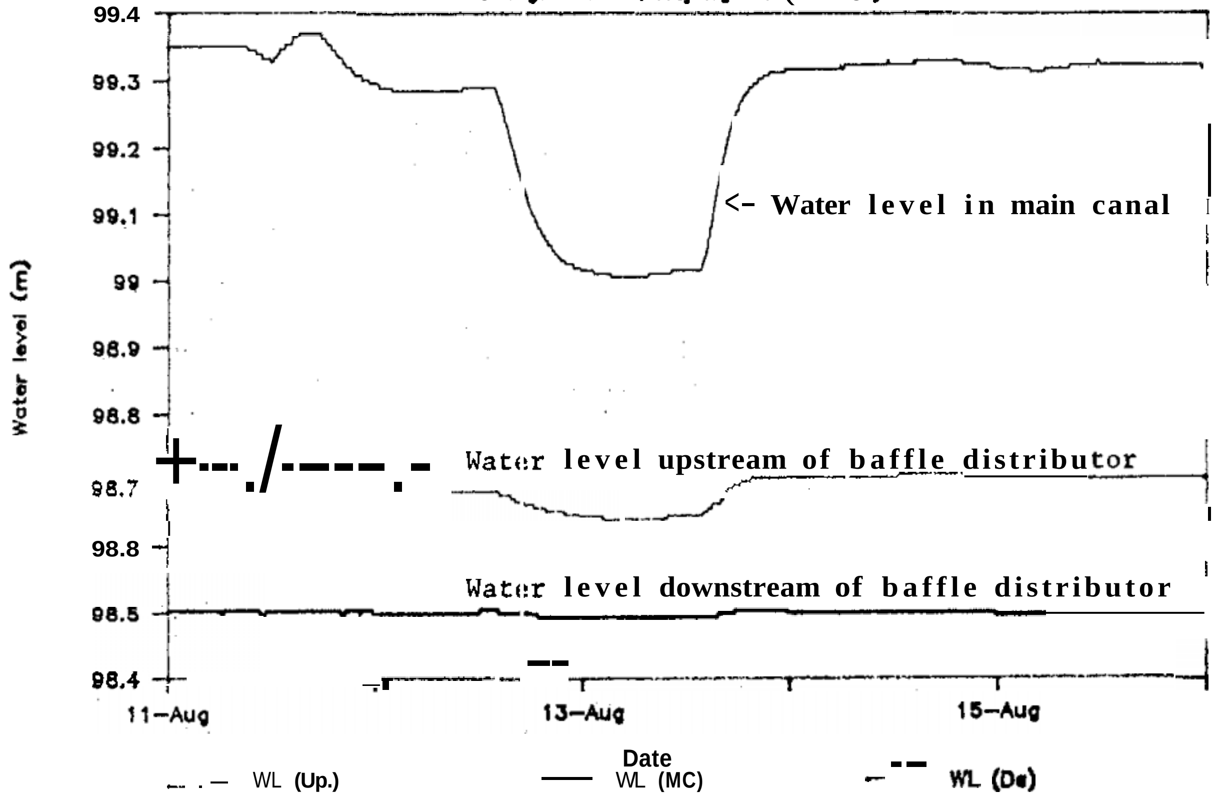


Figure 2 Comparison of discharges, pilot canal

11–15 August 1988, Rajangana (LBMC)

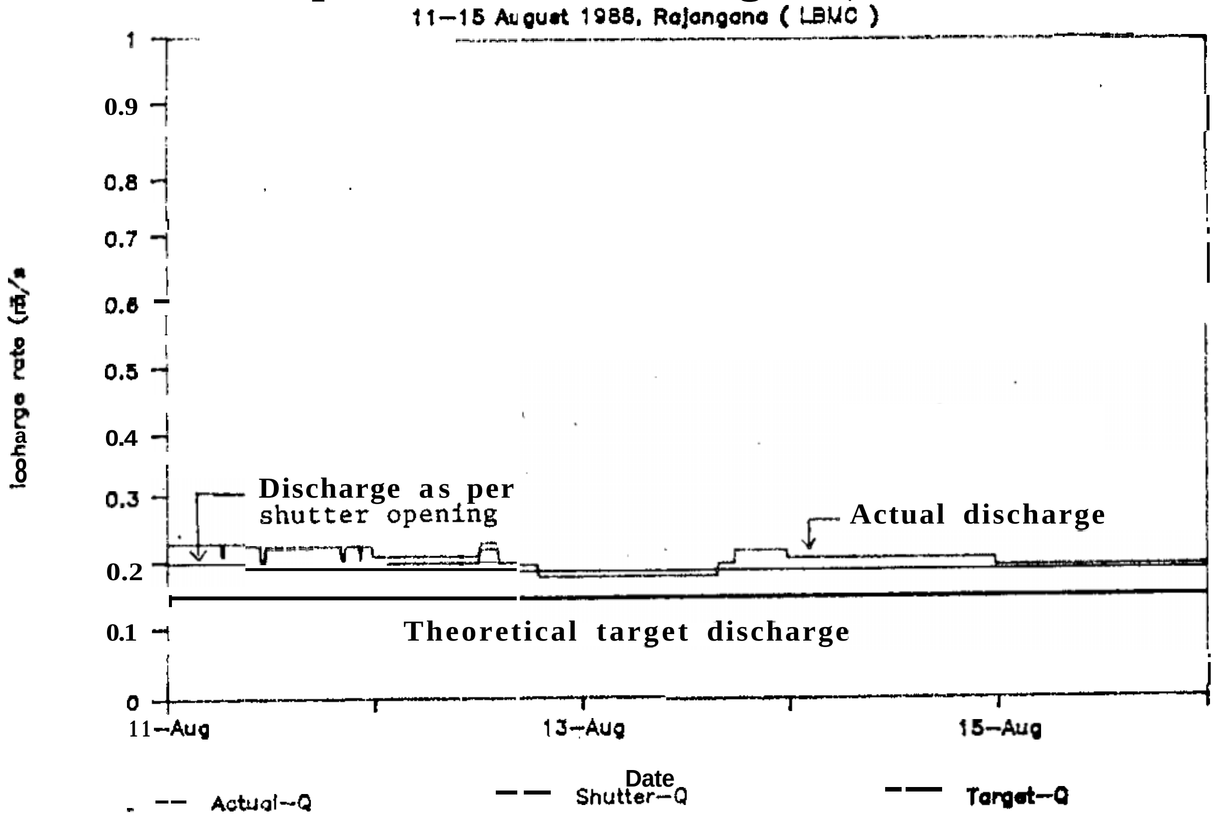


Figure 3 Comparlson water levels, control canal

11 – 15 Auguet 1988, Rajangana (LBMC)

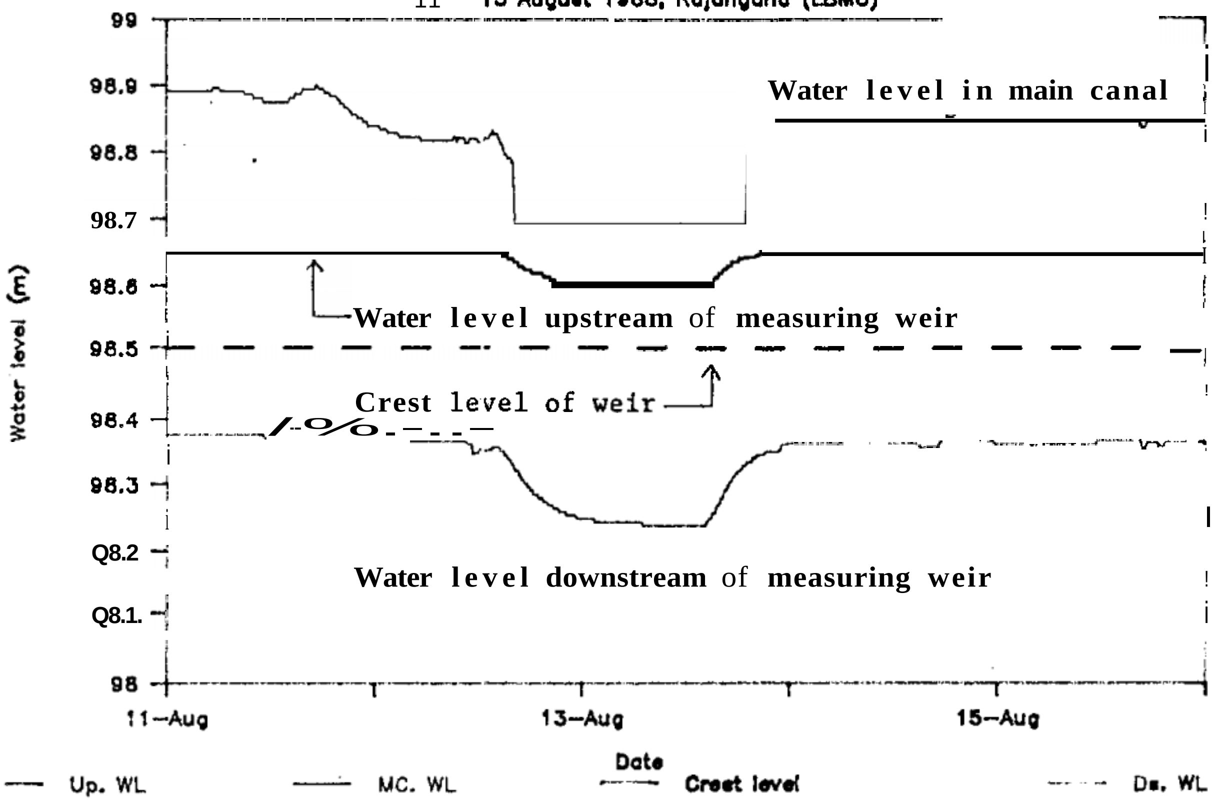
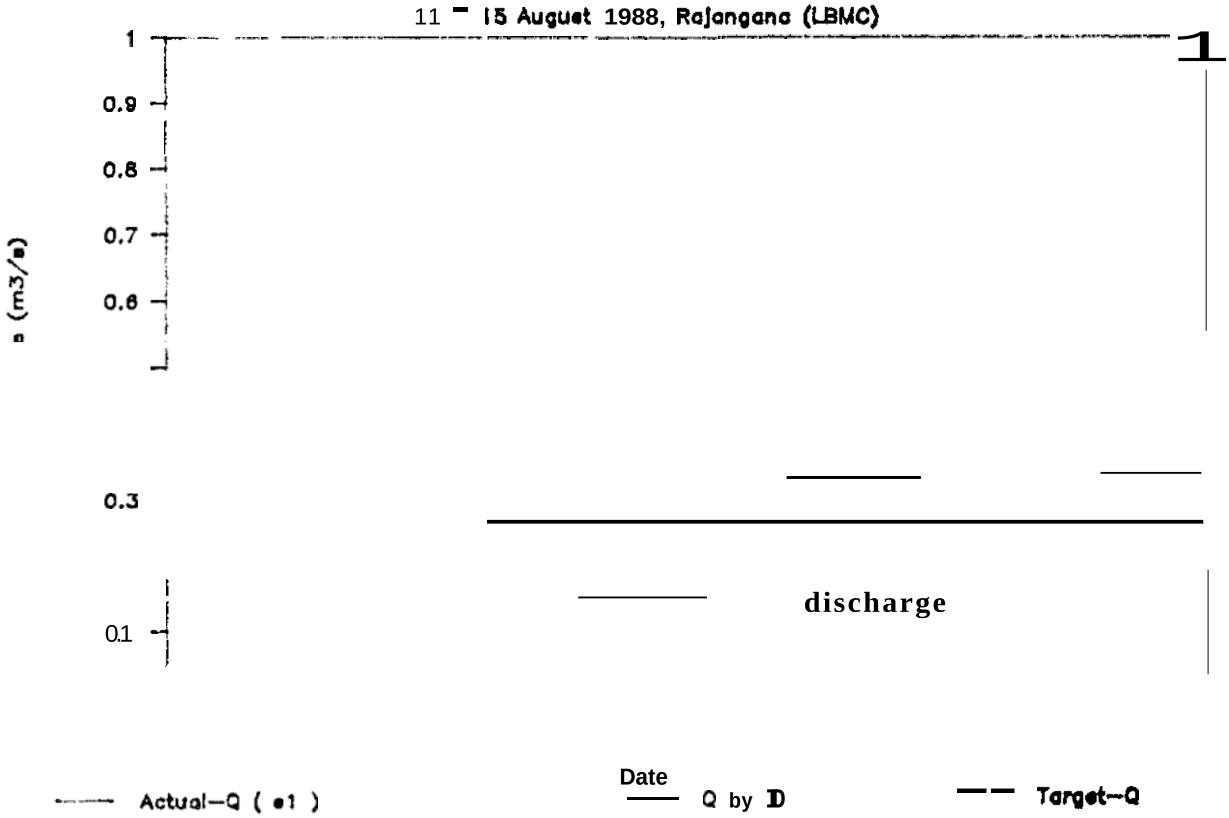


Figure 4 Comparison of discharges, control canal

11 – 15 Auguet 1988, Rajangana (LBMC)



ANNEX IV.2

Background note to demonstrate impact of submergence of the measuring weir on estimation of discharge at the head of branch canal 2, Kirindi Oya Right Bank Main Canal

Annex IV.2 : Background note to demonstrate the influence of the operation of the check gate across Branch Canal 2 on the submergence of the measuring weir at the head of the canal and its impact on the estimation of discharge at the head of Branch Canal 2, Kirindi Oya Right Bank Main Canal

(This note should be read in J ic with the accompanying figures

Episode 26 April-01 May 1988

No gate (offtake or cross-regulator) operations were permitted, and no adjustment to main sluice discharge took place during this period. This was on account of the measurement campaign aimed at calibrating the mathematical flow simulation model of the Kirindi Oya Right Bank Main Canal which was carried out during the period in question.

Conditions in the RBMC system were thus essentially steady except for the following rainfall events:

	Lunugamwehera	Wirawila
26 April 1988	3.3 mm	0
27 April 1988	5.8 mm	55.4 mm
28 April 1988	0	57.9 mm

The above data highlight the considerable spatial variation in rainfall between the head (Lunugamwehera) and tail (Wirawila).

The sudden rise in branch canal water level recorded around midnight of 26-27 April has not been due to an increase in main canal water level at the branch canal location or to gate interventions at either the nearby cross-regulator, GR12 or at the branch canal offtake itself. The most likely cause is the backwater curve generated by the closure of the check structure located in the branch canal around 100 meters downstream of the measuring weir.

Interpretation of this increase in branch canal water level by using the equation (equation 1 below) for free flow over a rectangular weir (as done by the Irrigation Department) leada to a corresponding increase in branch canal discharge, from 1.41 m^3/sec to 1.76 m^3/sec and finally to 1.95 m^3/sec.

But in reality this backwater phenomenon would tend to decrease the flow into the branch canal. This becomes evident if the flow is estimated on the basis of the offtake opening and the difference in water levels between main and branch canal (equation 2 below); the discharge falls from 1.34 m^3/sec to 1.22 m^3/sec and then to 1.15 m^3/sec.

The consequences of the two rainfall events at Wirawila on 27 and 28 April 1988 are shown as small increases in the water level records in the main and branch canal for this period. Again, different conclusions in respect of branch canal discharges would be arrived at depending on the equations used to compute flows at the head of this canal.

Use of the free flow weir equation would lead to a substantial increase in branch canal flow. For example, on **27** April, flow computed on this basis would show an increase from around 1.91 m^3/sec to 2.5 m^3/sec. Similarly on 28 April a discharge as high as 3 m^3/sec would have been computed.

However, on 28 April tie branch canal discharge would only have increased from 1.15 to 1.21 m^3/sec if computed by using the orifice flow relationship (equation 2) that integrates not only water level in the branch canal but also the offtake gate opening and main canal water level.

N.B. Equation 1 : $Q = 0.4\ L\ (2g)^{0.5}\ H^{1.5}$

Equation 2 : $Q = 0.618\ A\ [2g(S_1-S_2)]^{0.5}$

where
- Q = discharge (m^3/sec)
- L = length of weir at head of branch canal (meters)
- H = head of water above weir crest (meters)
- A = area of opening of offtake orifice (m^2)
- S_1 = water level in main canal (meters)
- S_2 = water level in branch canal (meters)
- g = acceleration due to gravity (9.81 m/sec^2)

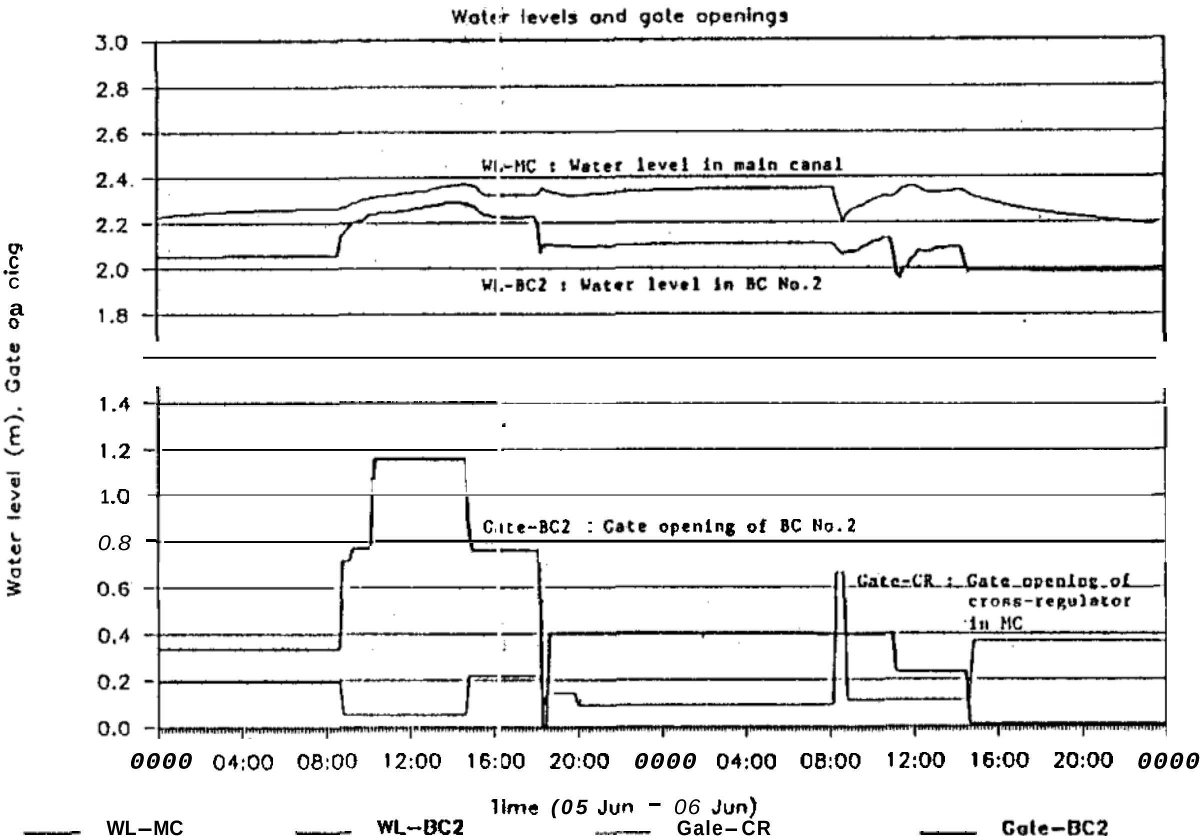
Episode 05 - 06 June 1988

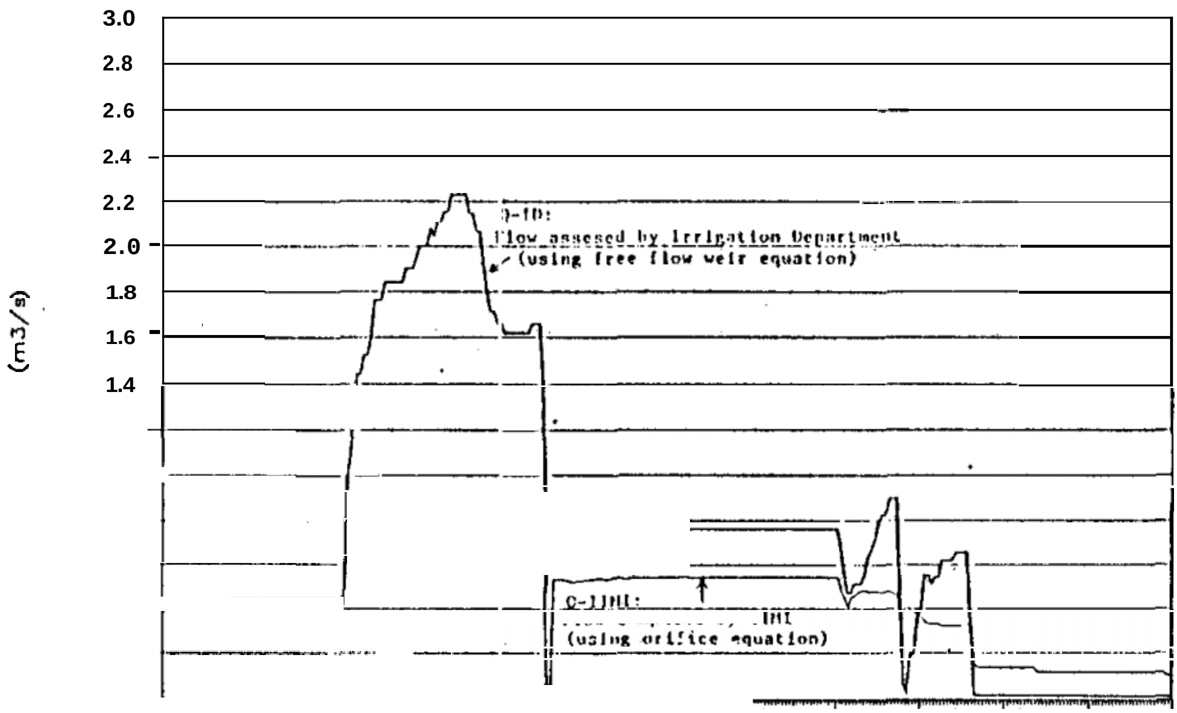
The influence of downstream conditions in Branch **Canal 2** on the estimation of flow at the head of the canal is also demonstrated by the events recorded between 5 and 6 June 1988. At around 1130 h on 6 June an IIMI Research Assistant closed the checkgate downstream of the branch canal offtake to carry out flow measurements at the head of the canal. This maneuver is typical of what might really occur, especially at low flows, to divert sufficient water into the two laterals (DC8 and FC6) taking off from the branch canal just above this check gate. The change (increase) in water level at BC2 is recorded by the datalogger. This increase in level can only be attributed to the change in the downstream condition in the branch canal because the main canal water level has not changed and neither the cross-regulator nor the offtake gate has been adjusted. Again, use of the free flow weir equation would lead to interpreting this change in branch canal water level as an increase in discharge, whereas the flow in fact dropped due to a reduction in differential head between main and branch canal.

Conclusion:

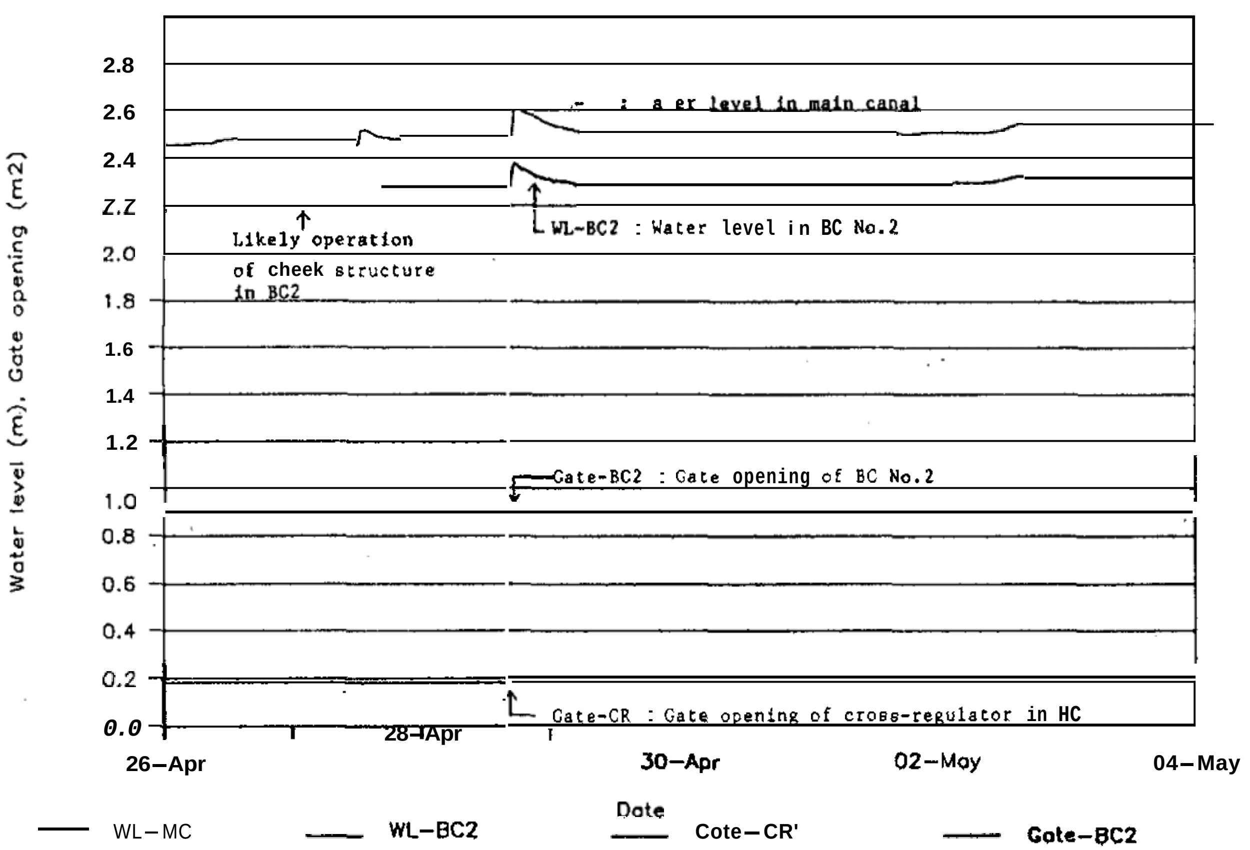
Effective and efficient system management requires proper estimation of flow delivered at different control points. Flow monitoring is complicated by physical and hydraulic problems existing at measuring locations. The above discussion highlights some of the precautions **and** practical difficulties associated with flow monitoring and the erroneous (and often diametrically opposite) interpretations of identical information that one might make, depending on the basic assumptions made in respect of physical and hydraulic conditions at the measuring site, This could have far-reaching consequences on system performance.

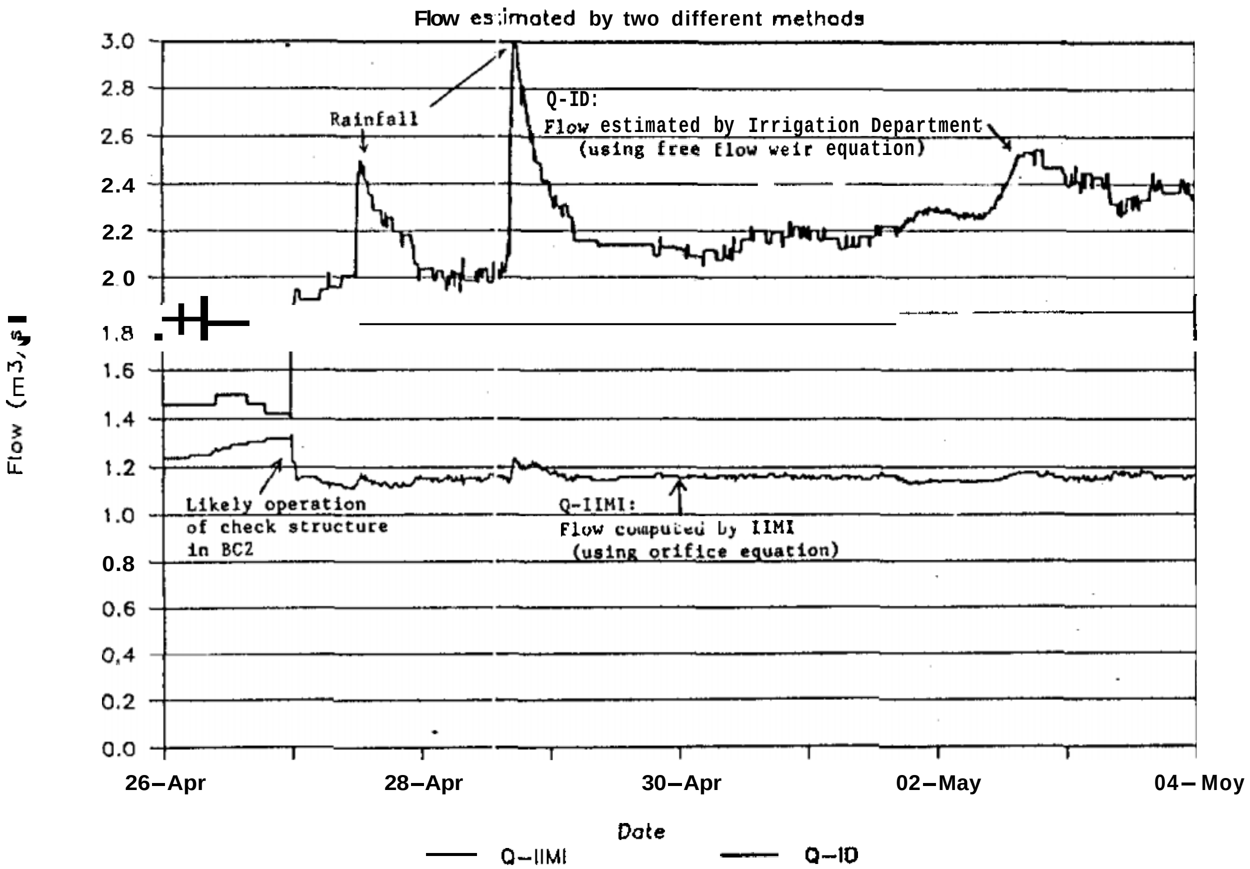
Kirindi Oya BC2: Estimation of flow





Kirindi Oya BC2: Estimation of flow





ANNEX IV.3

Typical analysis of data set acquired at
Kirindi **Oya RBMC/BC2 logging station, 27-28 March 1988**

Annex IV.3: Typical analysis of data set acquired at Kirindi Oya RBMC/BC2 logging station, 27-28 March 1988.

Following is a printout in tabular and graphic format of raw data acquired at one of the several logging stations installed by IIMI for the purpose of the study in Sri Lanka and in the Philippines. Four sensing devices located as indicated on the schematic layout at Kirindi Oya RBMC/BC2 were used and they permitted simultaneous records at each point. Interpretation of this particular time sequence is given below as an example of the type of analysis and understanding generated by these records with a view to evaluating the actual canal operation practices.

The rapid and simultaneous rise in the water level at S1 (upstream GR12) and the decrease at S4 (downstream GR12) indicate the obvious closure of gates of the cross regulator at 1300 h on 28/03/1988; this is further confirmed by the monitoring of gate operations carried out by IIMI. The problem is therefore to assess the rationale for such a particular operation and the consequences of it, given the normal operating rules to maintain water at 'Full Supply Depth (FSD) [Reduced Level (R.L.) 39.310 meters] upstream of the regulator GR12.

Since the middle of the night of 27-28 March 1988, the water level at GR12 has been rising above FSD. This apparently reflected higher flow in the main canal, which might be the result of heavy rain in the area and at Lunugamvehera (32 mm), earlier.. In the morning, the water was overflowing about 10 cm above the sidewalls of the cross-regulator, and the gatekeeper indicated in his field book that he opened the gates at 0723 h and 0830 h in an attempt to lower the level, but this does not seem to have been sufficient to bring it back to FSD. As a result of increasing discharge in RBMC and the subsequent backwater effect, downstream level at GR12 rose continuously since midnight and still more when additional water was released by the opening of the regulator gates of GR12.

At some stage, total outflow through GR12 and BC2 would have been greater than the main canal inflow and the reach upstream of GR12 soon started emptying. Around noon, water stopped overflowing the side walls of the cross-regulator. No longer controlled by the weirs, the water level dropped fast below FSD. This immediately prompted a fall in the discharge diverted into BC2, which was possibly below the target allocation.

At 1300 h, the gatekeeper at GR12 decided to intervene. Facing a situation where water was still unusually high in the downstream reach, he apparently decided to divert as much water as possible into BC2, used as a drainage facility. He first closed totally the gates of the cross-regulator at 1335 h, by which sidewalls were soon again overtopped, and he opened further the BC2 gate to divert most of the flow into BC2. The combined effect of the continuing rise in the main canal level for about two hours. before stabilization, and the opening of the offtake, altogether brought about 700 liters/sec of excess water into BC2 for the whole night (20,000 m^3 for about 8 hours).

As a hypothesis still to be confirmed by interviews with ID staff, the gatekeeper might have received information from the staff in charge of operation of the downstream reaches who are responsible for protecting a cofferdam located downstream. If *so*, the Water Irrigation Laborer (WIL) has purposely diverted water to prevent the risk of breach of that cofferdam built further down by the agency to raise head at the offtakes in the last reach,

The question now is to find out whether the earlier intervention made at GR12 in the morning according to the usual operational rules was opportune, whether it has put the cofferdam at risk, inducing a remedial action that put to waste 20,000 m3 of water, and if *so*, what would have been a more appropriate action.

Figures 1 & 2 present the variation of water level upstream and downstream of the cross-regulator GR12 as recorded by the datalogger. Plotting these in Reduced Levels permits to compute the hydraulic head over the gate of the regulator and over its appurtenant side walls. Side walls of regulators are usually erased at Full Supply Depth level (R.L. FSD at GR12 = 39,310) and participate to some extent in the control of level over the weir. Figure *2* permits to evaluate the effectiveness in controlling FSD level at the regulator over time. It shows that during these two days, the water level in the main canal has been above FSD most of the time, even before the complete closure of the regulator GR12.

Figure 3 presents the record of gate operations as maintained by the gatekeeper (WIL). Actual gate opening was computed from indications of spindle height of each gate and calculation of the total orifice area at the cross-regulator GR12 (4 gates) and at the Lateral BC2.

It matches fairly well with the variation of level recorded by the logger that reflects changes in the gate setting, an indication of confidence which can be placed in that particular set of data.

Figure 4 presents the result of an estimate of respective flow variation in time at GR12 and BC2. This was made by calculation of discharges passing through gates and over side walls at the regulator. Theoretical equations were used with a discharge coef'ficient adjusted on available gauging made by IIMI, in association with similar records and information on gate setting at that time.

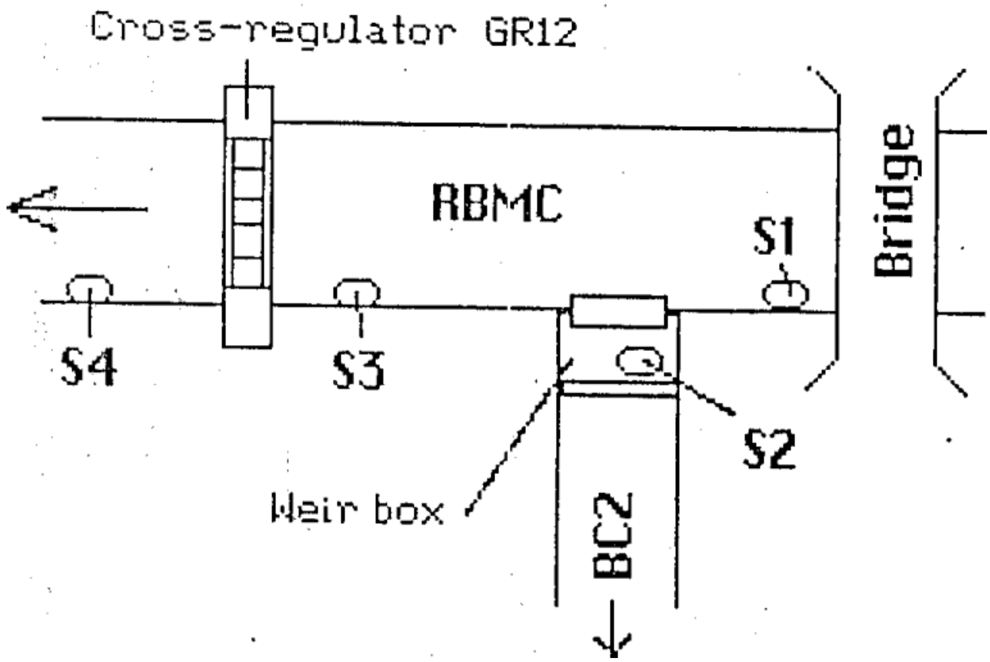
This evaluation permitted to assess the impact of that particular sequence of gate operations in respect to the outflow in both directions at RBMC/BC2 diverting point. Due consideration has to be given in the interpretation of the graph for temporary imbalance of inflow/outflow that results in storage variation in the main canal reach for sometime after a gate intervention.

Figure *5* presents the results of a comparative evaluation of flows at the BC2 by computation using two sets of data: (i) the differential head over the gate orifice (S1 minus S2) and record of gate opening, and; (ii) the water level in the weir box (sensor S2) that corresponds to the staff gauge readings currently used by the agency to assess discharge at BC2. In the first case, computation has been made with the ori'fice equation and a discharge coefficient (0.61) derived from the available gauging performed on that canal and simultaneous records. In the second case, the free flow weir equation is used for comparison purposes.

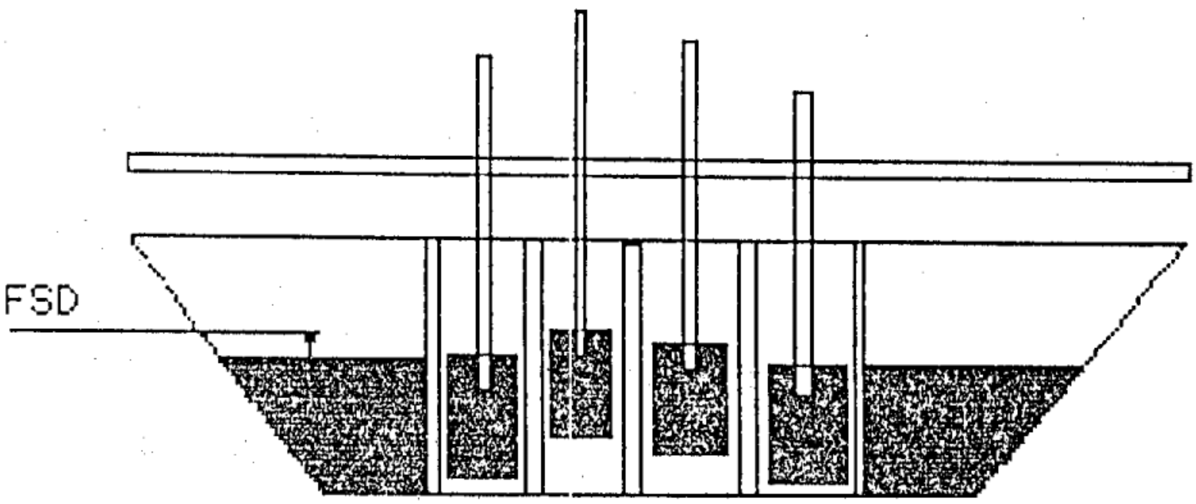
As a matter of fact, calibration of that particular staff gauge [installed by IIMI) has not been successful. Although physical conditions of the weir are good, this structure appears to be subject to submergence depending on discharge and downstream operations of the DCs, and thus the level of water at the weir box alone is not enough for calibration of BC2. Figure 5 illustrates the occurrence of these phenomena for the highest flows. On the other hand, BC2's flow estimated with the orifice equation is consistent with most gauging performed by IIMI throughout the season.

KIRINDI OYA RBMC/BC2

Location of the four sensors

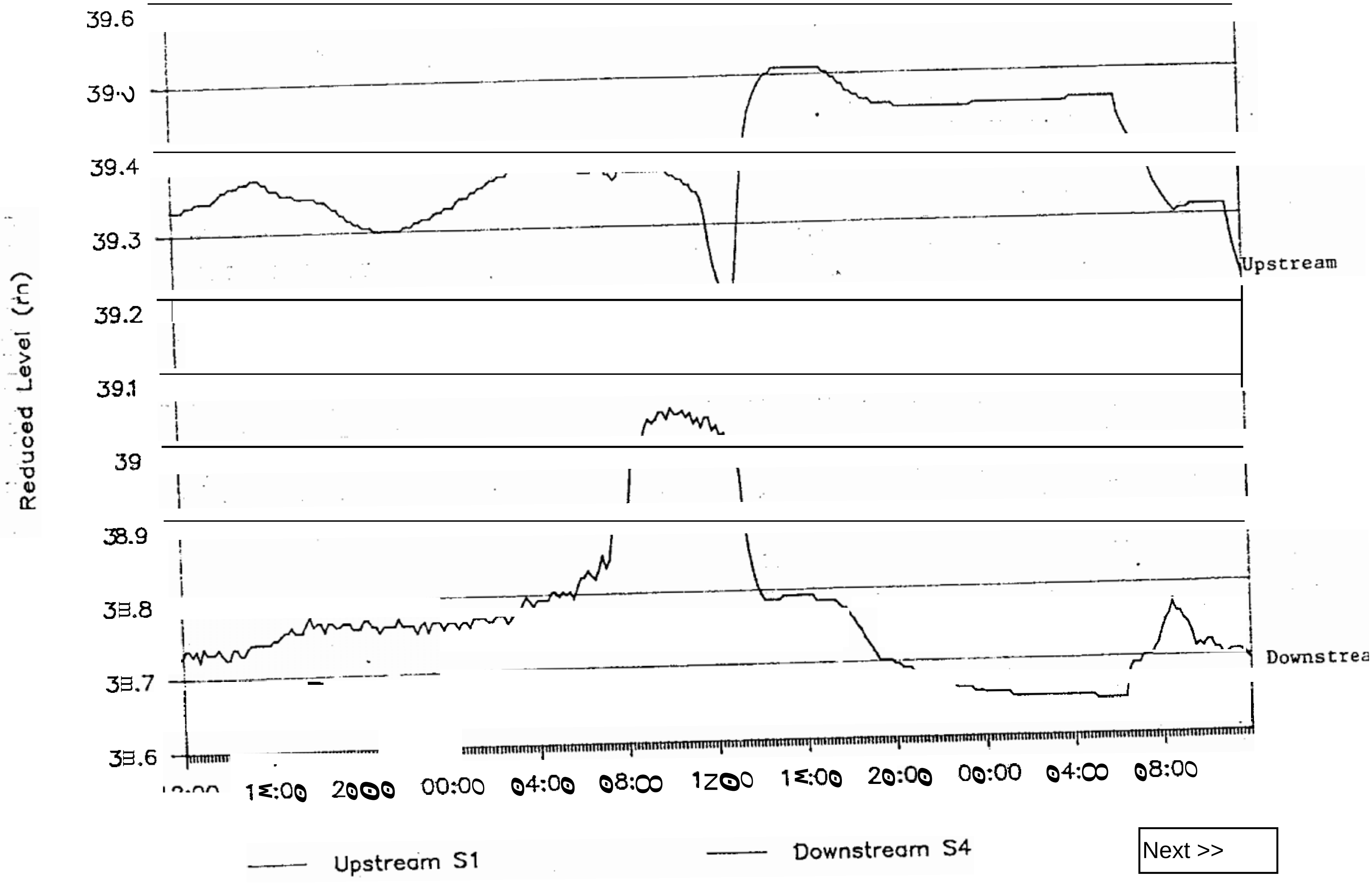


SCHEMATIC OF A CROSS-REGULATOR



Side-walls erased at Full Supply Depth level (F.S.D.)

Figure 2. GR12 - Levels upstream and downstream, 27 March 1988 1200 h to 29 March 1988 1200 h.



Next >>

complex, and the effective management of these structures under dynamic conditions requires managerial capacities which are seldom currently available within agencies.

A technology that has proven to be effective in alleviating these difficulties at the level of the distribution system is the provision of simpler hydraulic control structures in the main canal offering less operational flesibility (like **the** duckbill weirs displayed along the Iialankuttiya Branch Canal).

9. The operational arrangements available to perform the **task** .of regulating the conveyance of water at the appropriate intermediate operational level in the systems studied appeared fa:: less developed and sometimes nonexistent.

10. An important aspect to be considered in a rational approach to the design and management of main systems and subsystems, is the nature of the dependencies built in between the physical processes to be performed (conveyance and delivery,.)on the one hand, and the different managerial processes associated with these (delivery level, regulatory level, resource management level), on the other.

Rational and functional designs should provide some domain. of freedom for the operation of subsystems at lower levels, with the view to improve the manageability, responsiveness, and performance of the overall system. These could be, for instance, in the form of physical buffer capacities like an intermediate tank between the conveyance and distribution systems. Management of storage in this tank becomes the main **task** of the higher-level system. This is similarly achieved through the allocation at the right managerial level of decentralized responsibility over subsystems.

In such an arrangement, the administrative-managerial level in a position to oversee the whole canal should be entrusted with the operational task of regulating the conveyance of water in the main anal. Decisions regarding operation of the regulating structures should be retained at that level, while the room for decision making of lower-level operators with respect to the conveyance of water should be minimized.

This is obviously a major departure from current operational practices of agencies which aim to "regulate" the conveyance through standing orders given to the operators and to ininimize the need for information communication between managerial levels. On the contrary, the availability of communication facilities at the intermediate managerial level to get adequate feedback regarding the ongoing process of water transfer (at key locations), and to communicate timely, specific instructions to the operators, is the critical factor for a regulation approach, unless these important constraints are alleviated by some degree of automation (downstream control).

11. Dependencies between physical processes *can* be either loose or tight, hut the planning and design of irrigation systems play key roles in setting the nature of these dependencies and by doing so determine the potential manageability of systems.

12. Finally, the managerial efforts required for control of the primary distribution of water from the main canal can be incommensurable between systems depending upon whether the functional aspects associated with regulation of the conveyance of water through main systems and control of water delivery have or have not been adequately considered at the initial planning and design stage.

If not, managerial capacities which are not currently available within irrigation agencies might be required, and control of water deliveries might be, in some cases, an unrealistic objective. Substantial rehabilitation and modernization to accommodate a rational and functional approach for operation of canals may be needed in such cases.

In summary, improvements can be expected under a rehabilitation and modernization program through the following:

A. Structural improvements through better planning, design, and construction:

A.1. Structuring the main system in a functional way with due consideration for the primacy of the conveyance of water which has to be achieved through the main canal, and providing buffer capacity (intermediate storage, in-line canal storage, etc.) between the conveyance and distribution systems (but existing systems might have limited scope for such improvements).

A.2. Simplifying the hydraulics of canals and their structures through the rational use of hydraulic "controls" (weirs) to substitute for human control wherever permitted by the topography.

B. Managerial improvements through organization design and information communication:

B.1. Structuring the organization in a functional manner, recognizing the primacy of the conveyance function and providing the corresponding administrative-managerial unit, appropriately located within the hierarchy of the agency, whose sole responsibility will be the operation of the conveyance system; the staff of this unit ehould be distinct from that engaged in operating the subsystems.

B.2. Coordinating and tightening the operations of structures along main canals through more integrated management at the main canal level; the ability to monitor, process, and communicate information in real-time between the operator; and management is a key element; the widest possible range of management techniques and technology should be explored for this purpose including both hardware and software options.

ACKNOWLEDGEMENTS

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The material was contributed by IIMI's field research staff, Messrs. Wilfredo Ramos and Rcdelio Navarez in the Philippines, and Messrs. S. Pathmarajah and Asoka Hingurahena in Sri Lanka.

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Special thanks is due tc Mr. Jayanthakumar Arumugam for his assistance in processing the data collected through the electronic dataloggers and for most of the graphic prcductions and to Mr. D.W. Bandara; to Mr. T.M.K. Wijesinghe for drawing some of the figures, Mrs. Chandrika Jayawardena for secretarial assistance, and the editorial staff, all of IIMI.

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Figures

Figure II.1 Comparative presentation of the schematic layouts of the main systems studied

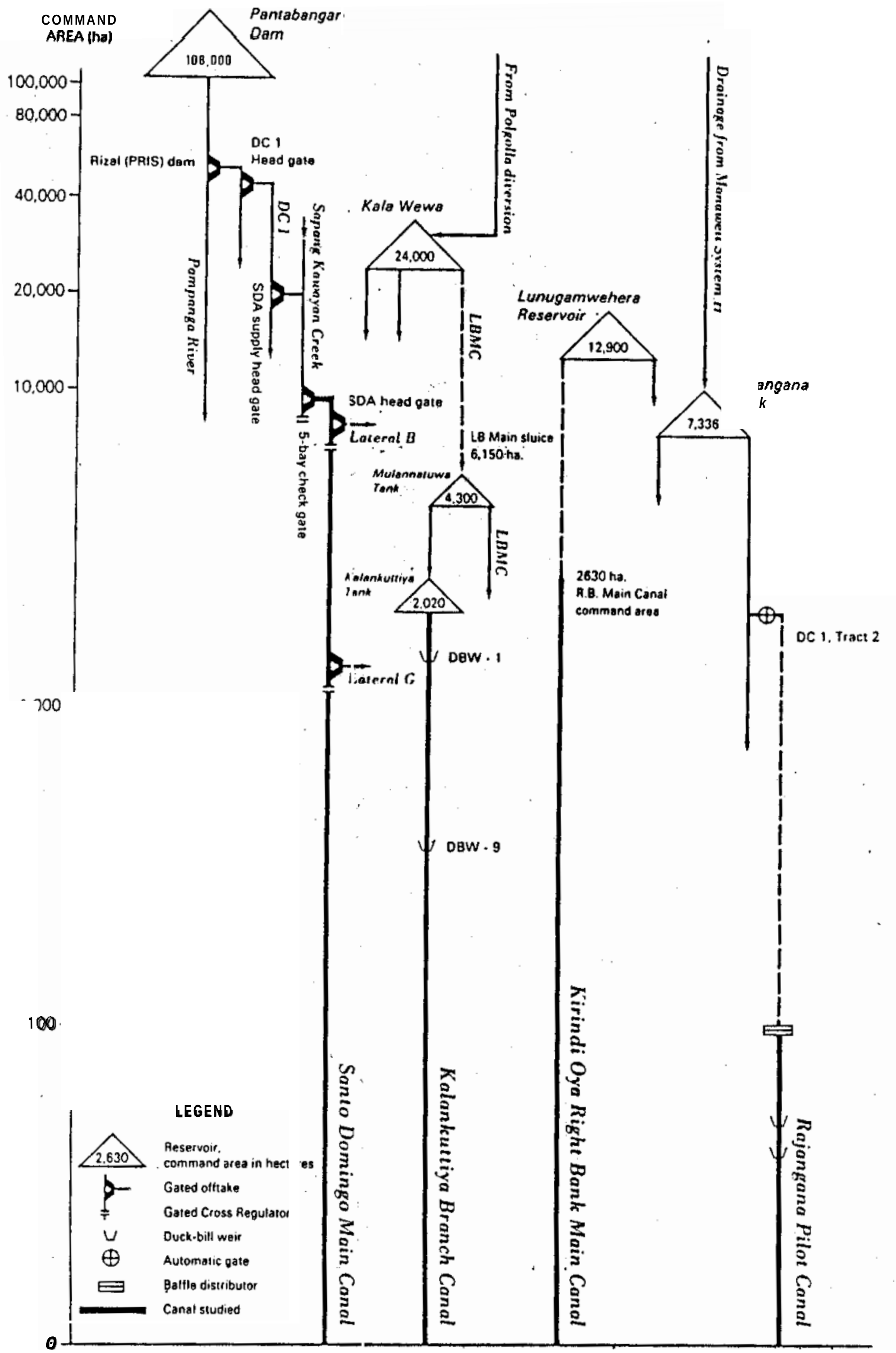


Figure II.2 Kirindi Oya Irrigation and Settlement Project

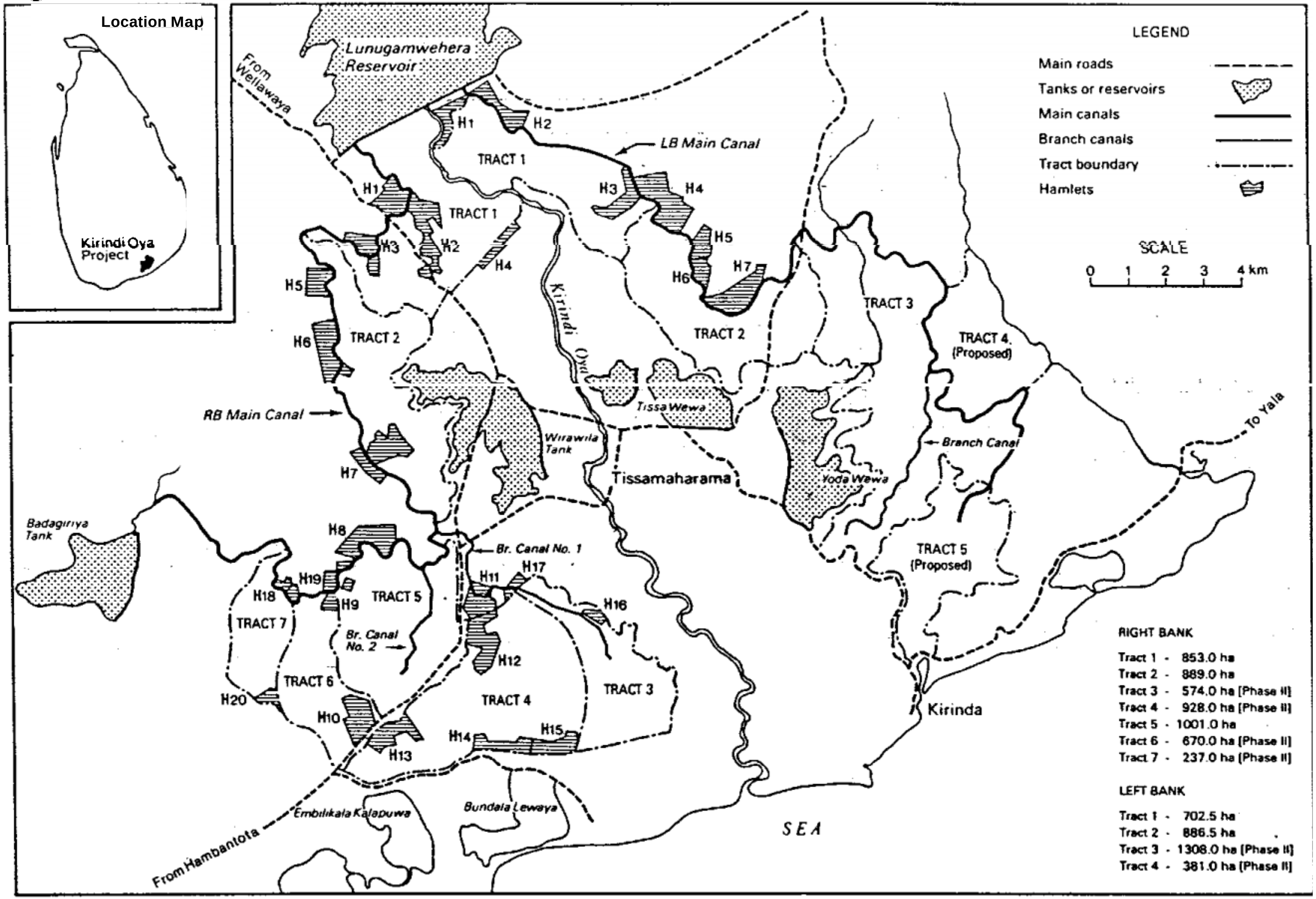
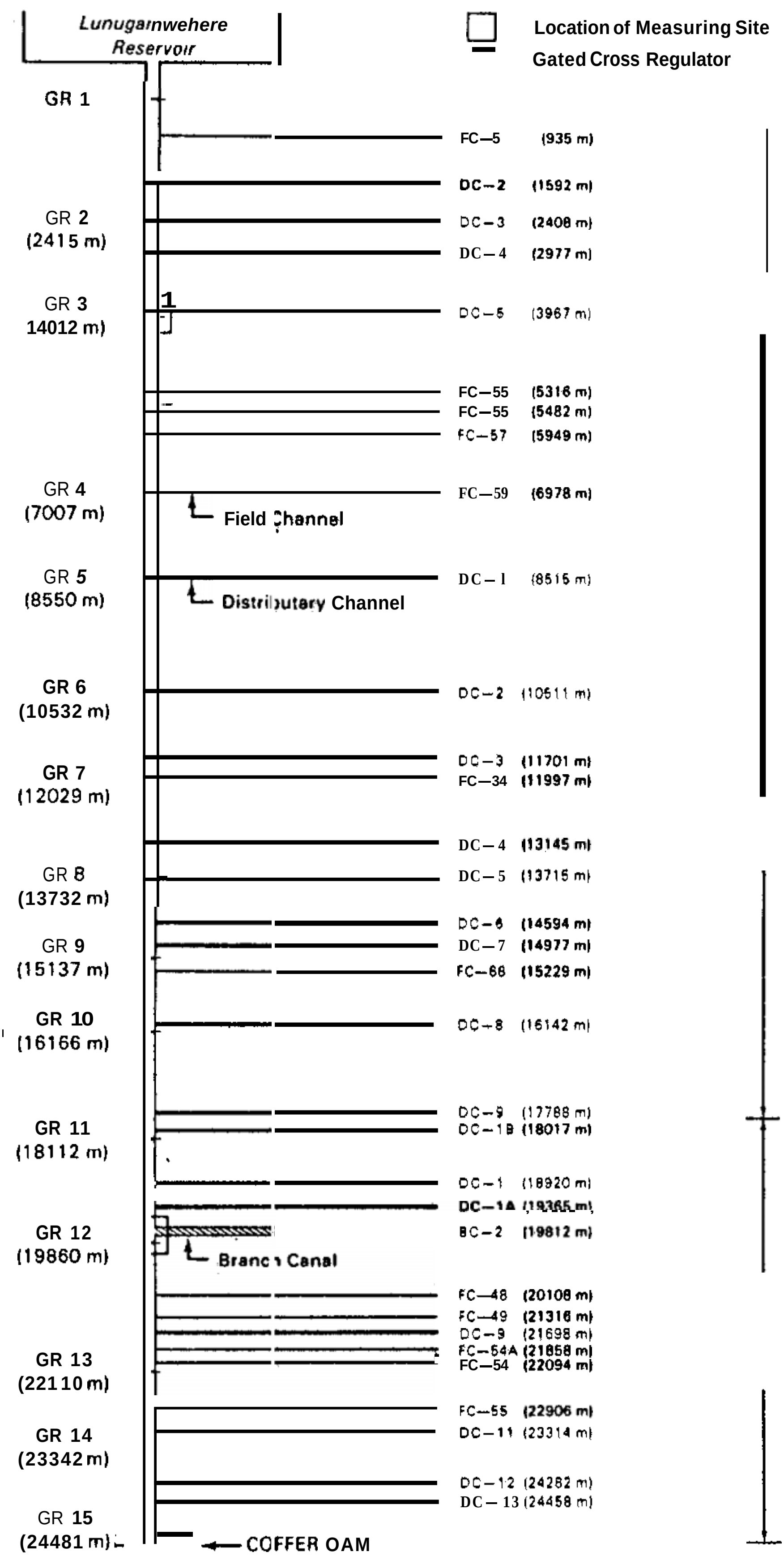


Figure 11.3 Issue tree diagram Kirindi Oya Right Bank Main Canal



ure II.4 Mahaweli Canga **Development** Project, **System** H

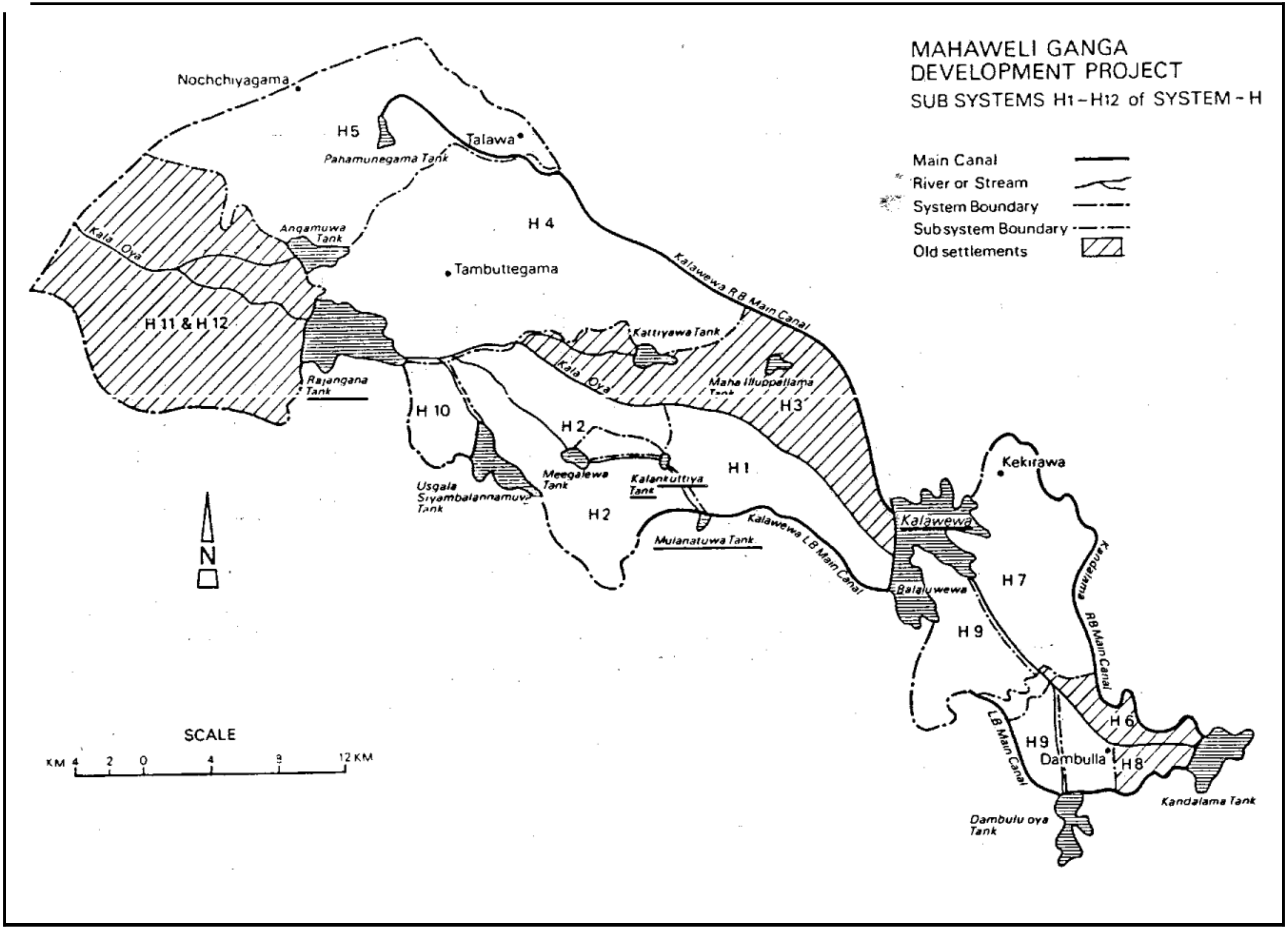


Figure II 5 Kalankuttiya Block of Mahaweli System H

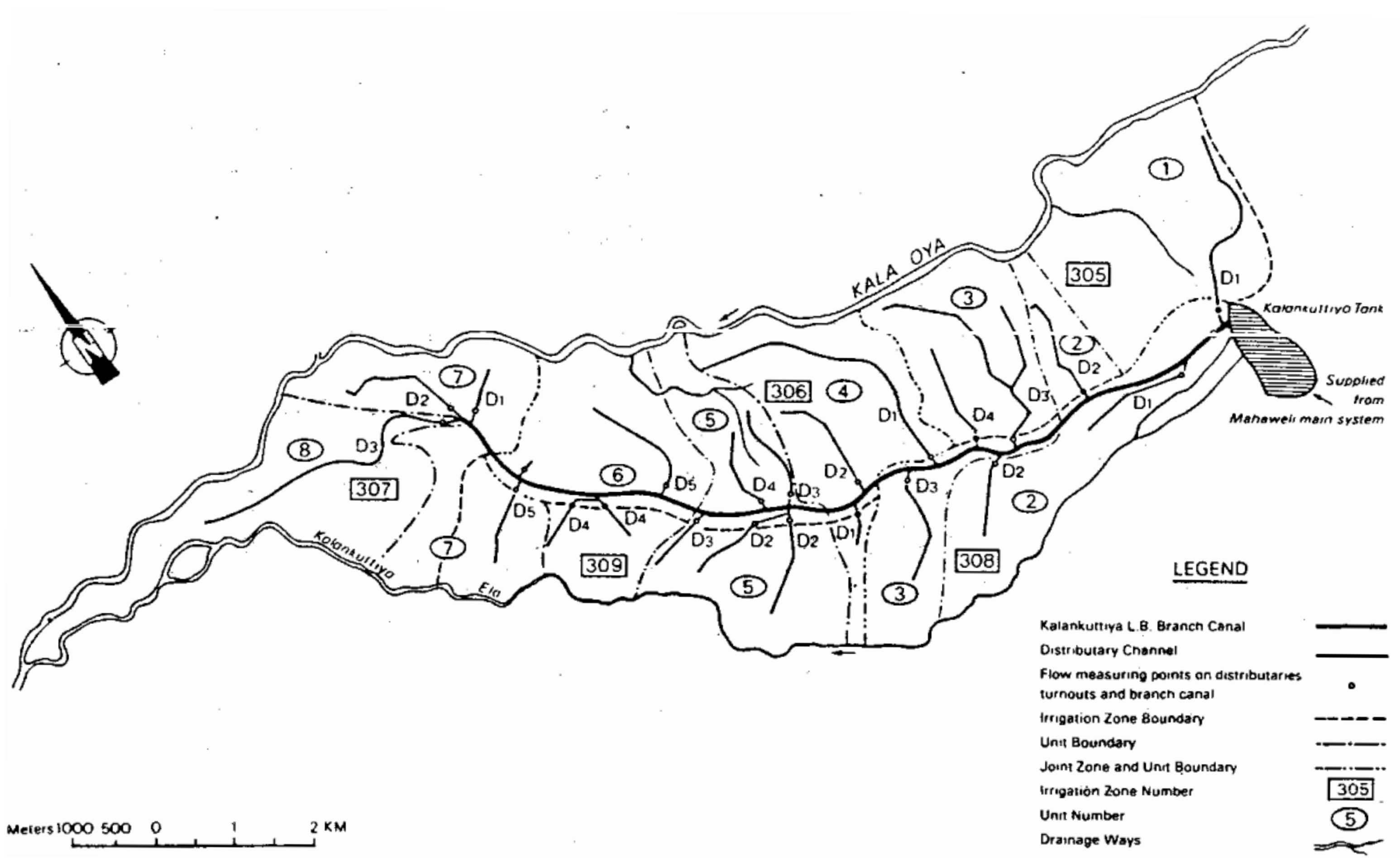


Figure II.6 General Layout of UPRIIS Service Area

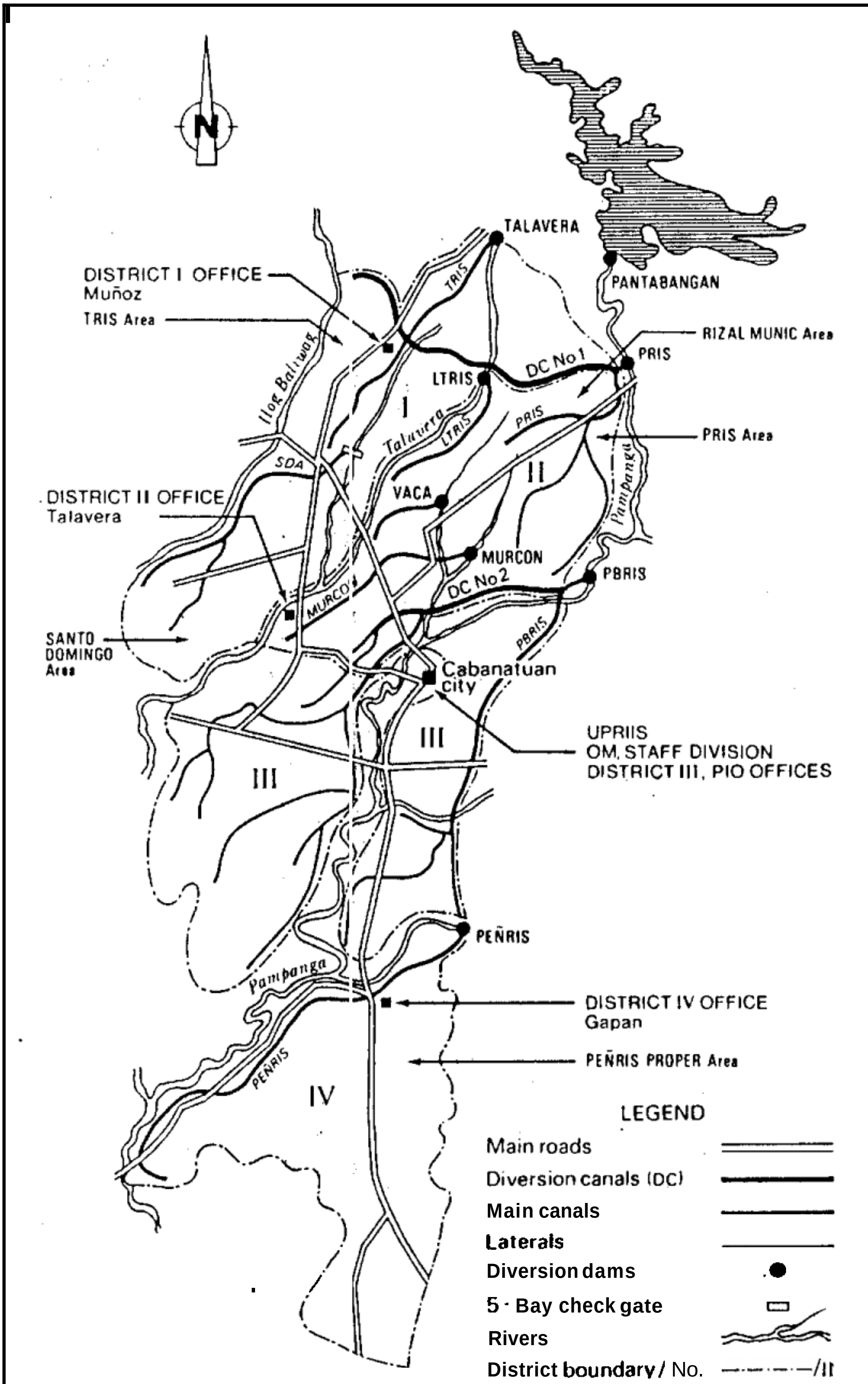
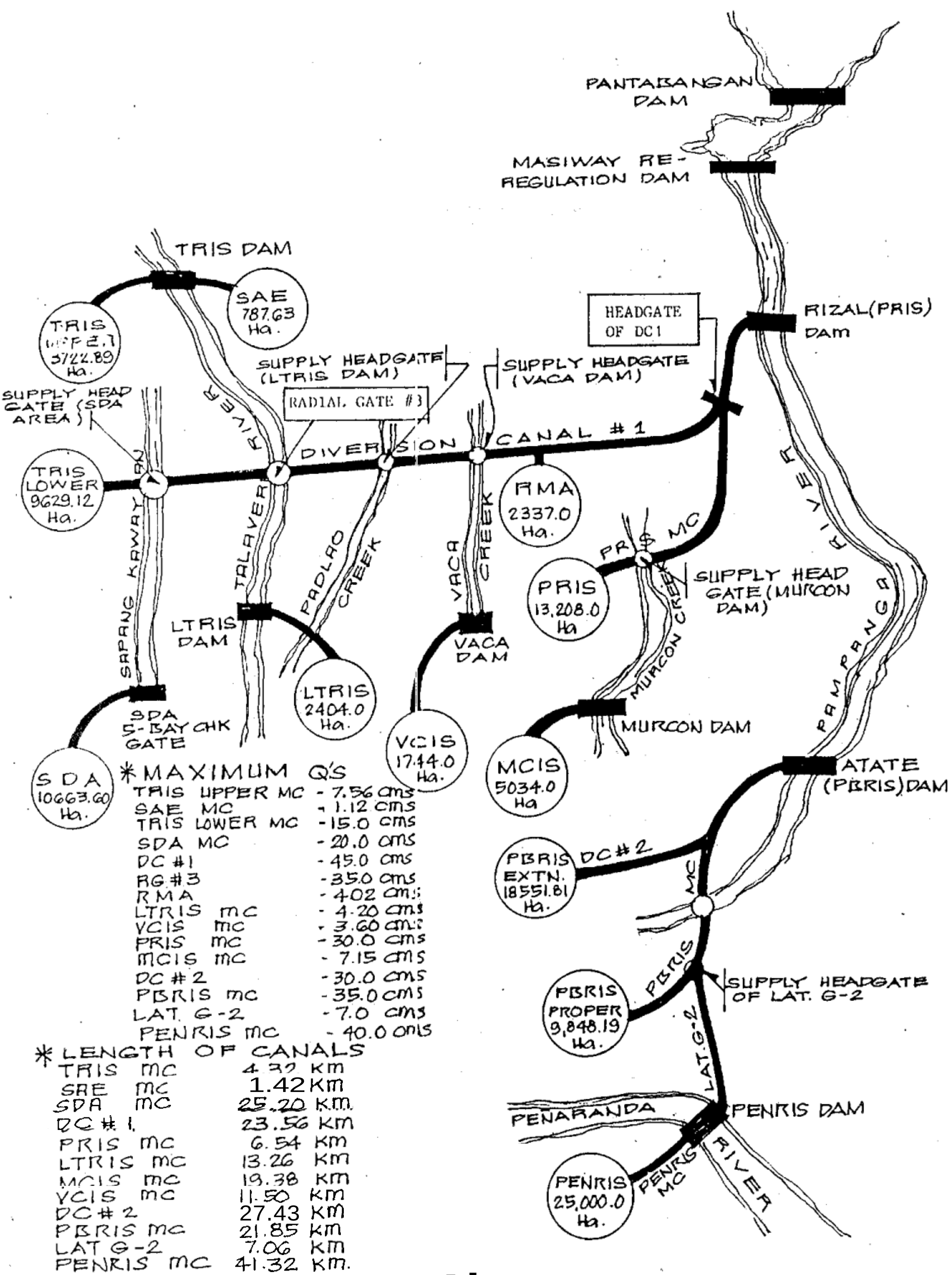


Figure II.7 IRRIGATION NETWORK
(UPPER PAMPANGA RIVER INTEGRATED IRRIGATION SYSTEM)



*MAXIMUM Q's

TRIS UPPER MC	- 7.56 cms
SAE MC	- 1.12 cms
TRIS LOWER MC	- 15.0 cms
SDA MC	- 20.0 cms
DC #1	- 45.0 cms
RG #3	- 35.0 cms
RMA	- 4.02 cms
LTRIS mc	- 4.20 cms
VCIS mc	- 3.60 cms
PRIS mc	- 30.0 cms
MCIS mc	- 7.15 cms
DC #2	- 30.0 cms
PBRIS mc	- 35.0 cms
LAT. G-2	- 7.0 cms
PENRIS mc	- 40.0 cms

*LENGTH OF CANALS

TRIS mc	4.32 km
SAE mc	1.42 Km
SDA mc	25.20 km.
DC #1	23.56 km
PRIS mc	6.54 km
LTRIS mc	13.26 km
MCIS mc	19.38 km
VCIS mc	11.50 km
DC #2	27.43 km
PBRIS mc	21.85 km
LAT G-2	7.06 km
PENRIS mc	41.32 km.

Figure 11.8 Schematic diagram of Santo Domingo Area (SDA) irrigation network

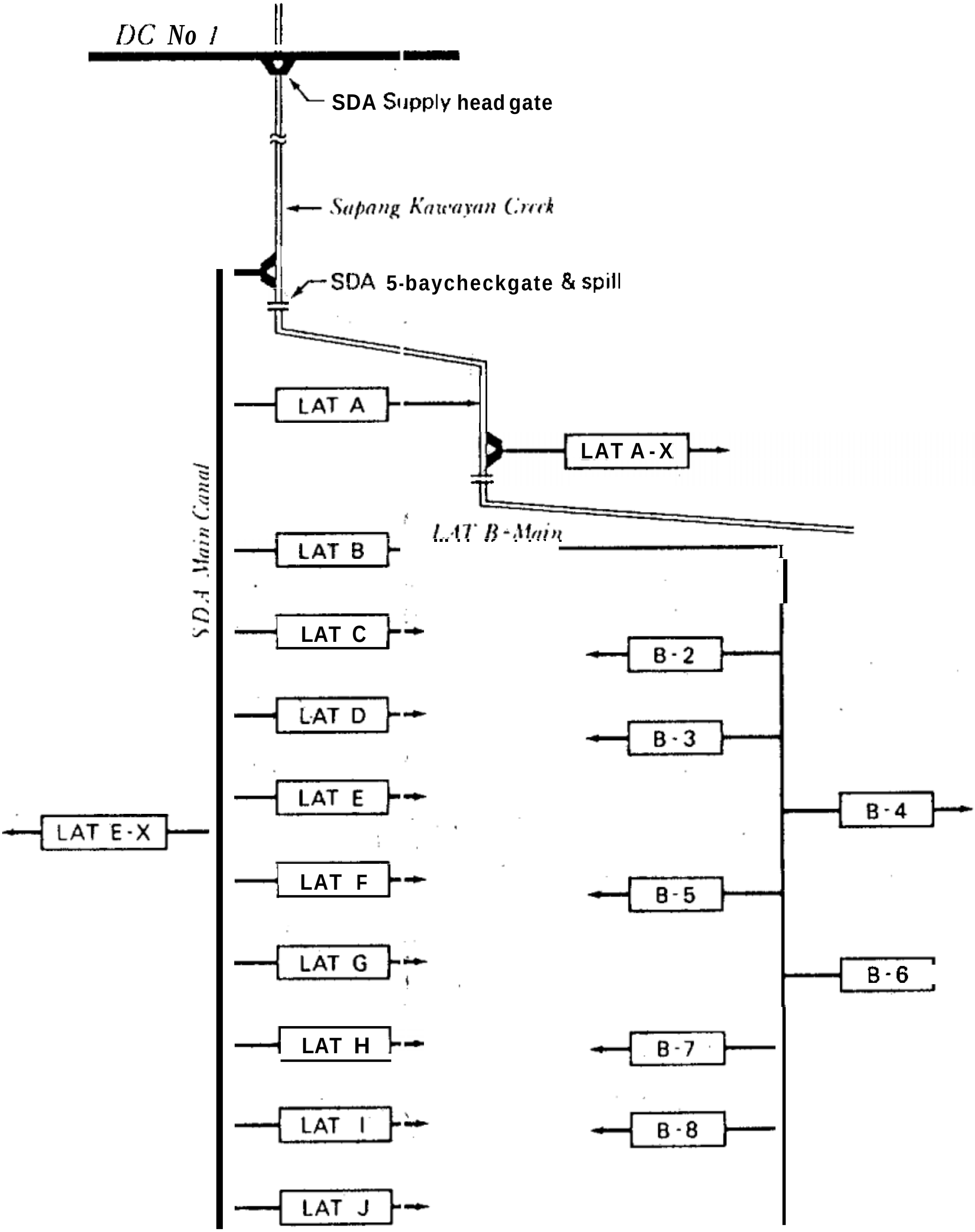
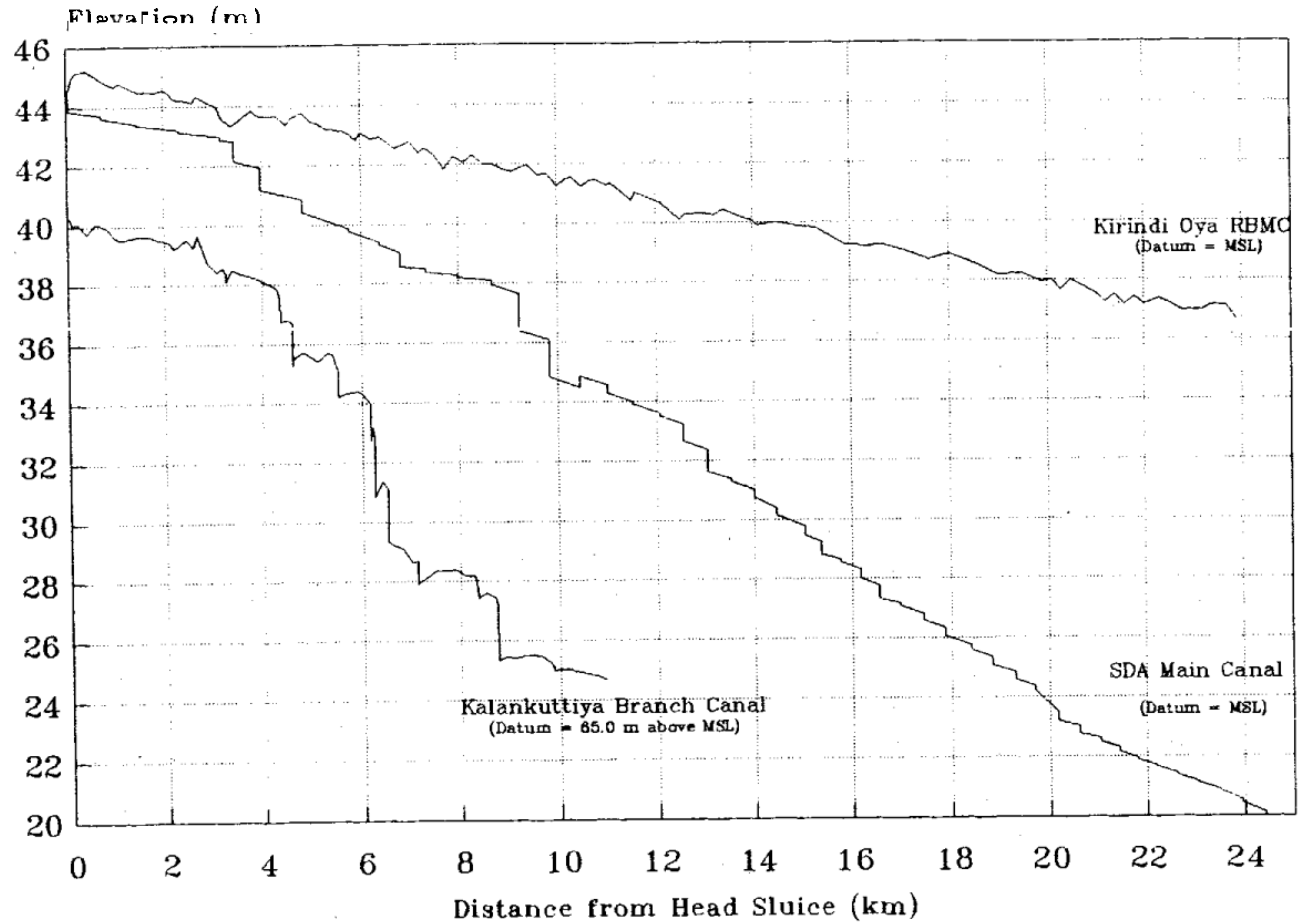
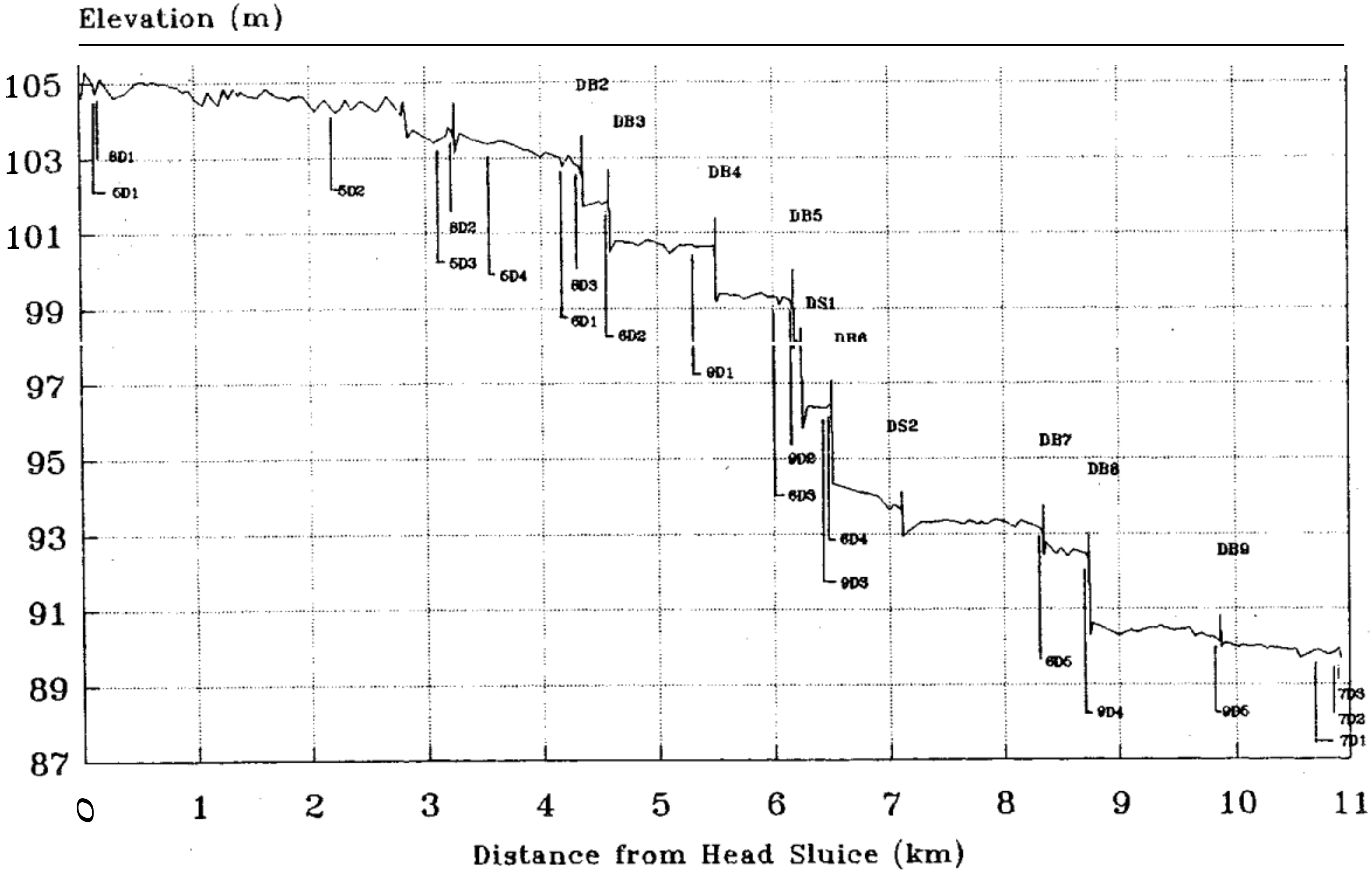


Figure II.9 LONGITUDINAL PROFILES OF CANALS STUDIED



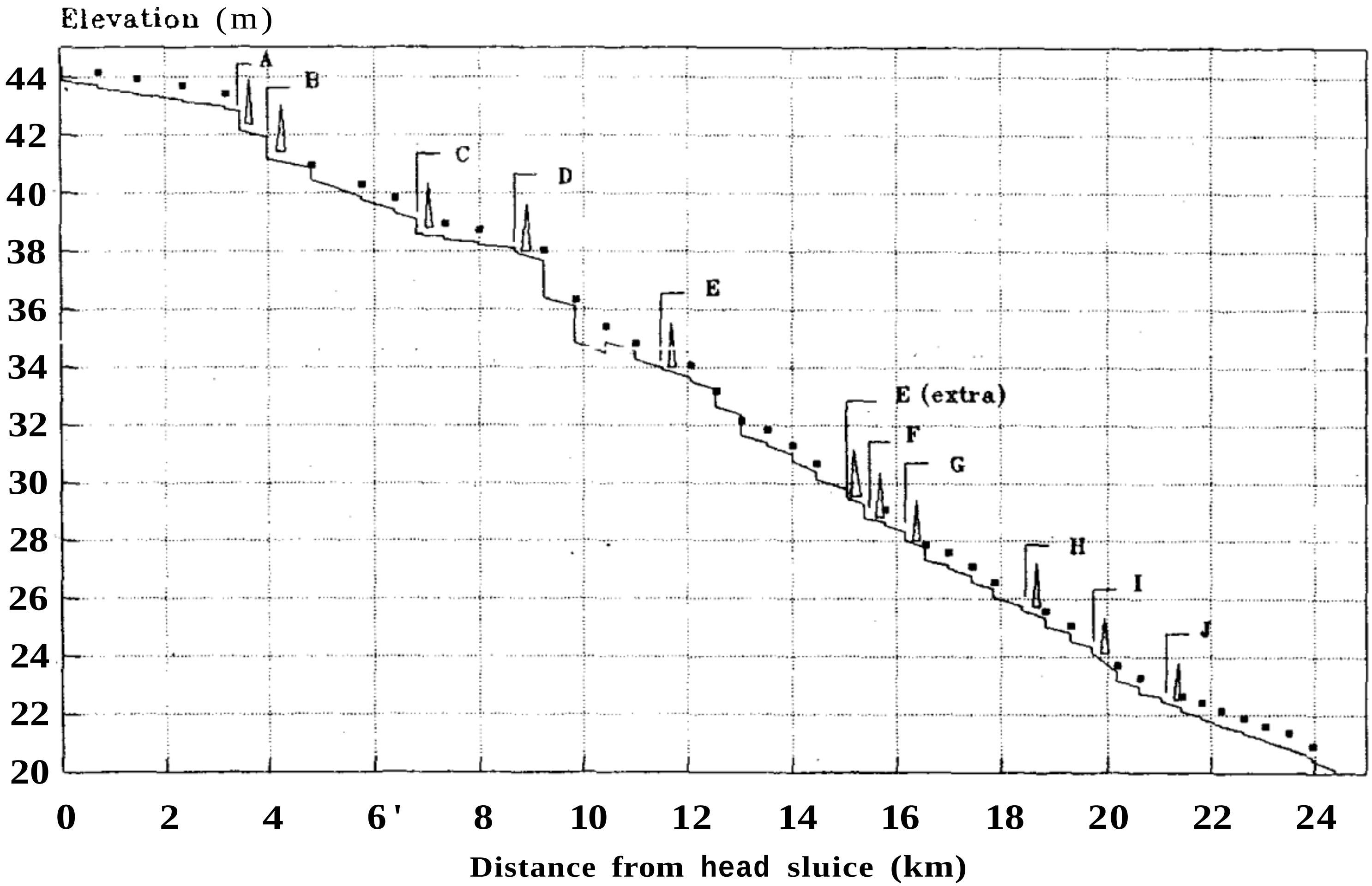
MSL = Mean Sea Level

Figure II.10 KALANKUTTIYA BRANCH CANAL LONGITUDINAL PROFILE



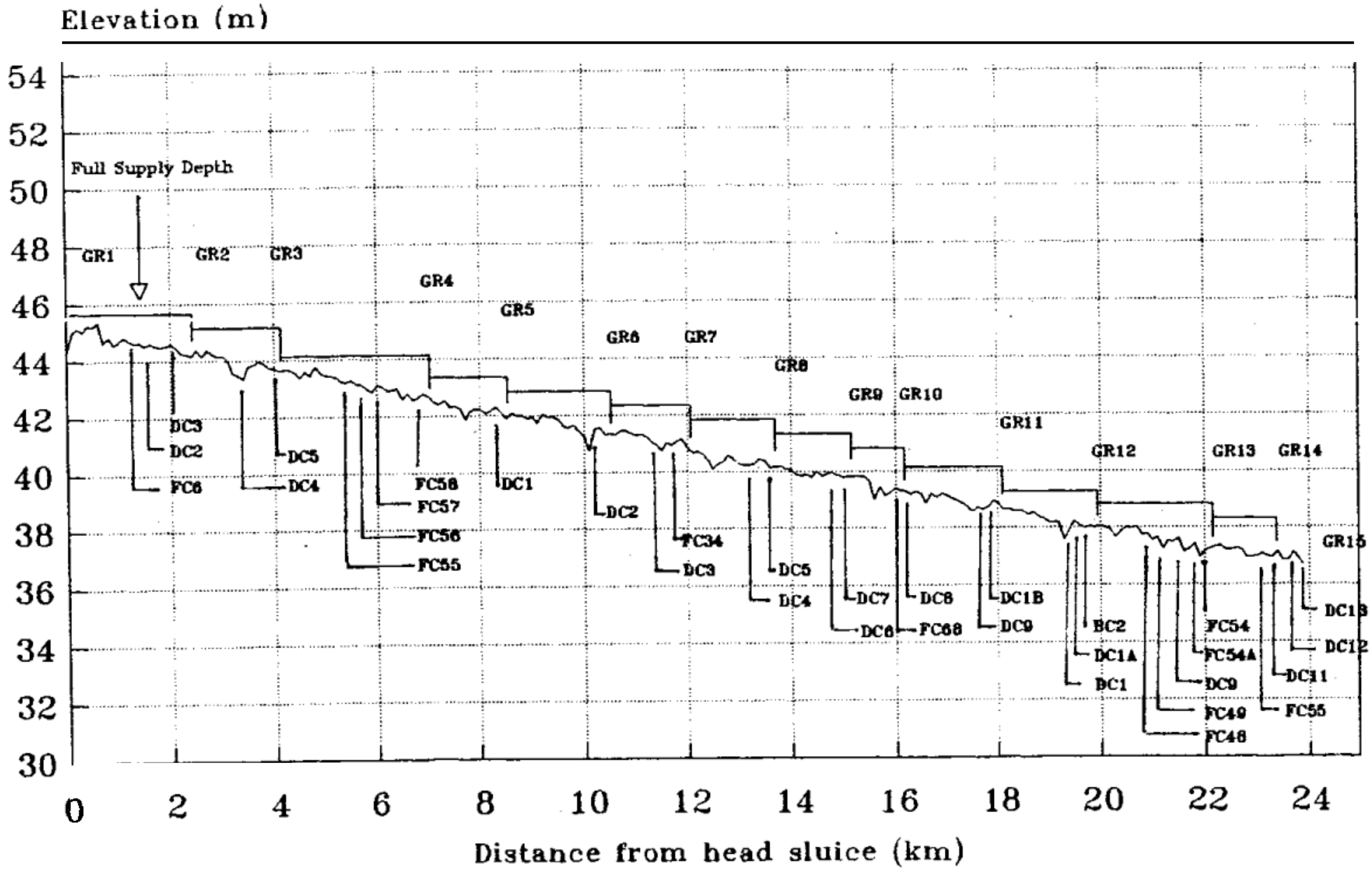
5D1−7D3 : Distributary canals (20)
GR : Gated cross regulator (1)
DB/DS : DuckBill weir/DropStructure(9/2)

Figure II.11 SDA MAIN CANAL
LONGITUDINAL PROFILE



A-J : Laterals (11)
: Gated cross regulators (11)
: Other check structures (35)

Figure II.12 KIRINDI OYA RIGHT BANK MAIN CANAL LONGITUDINAL PROFILE



GR : Gated cross regulator (15)
FC/DC : Field/Distributary Canal (33)
BC : Branch Canal (1)

Figure 11. 13 Kalankuttlya branch canal: Issue tree diagram

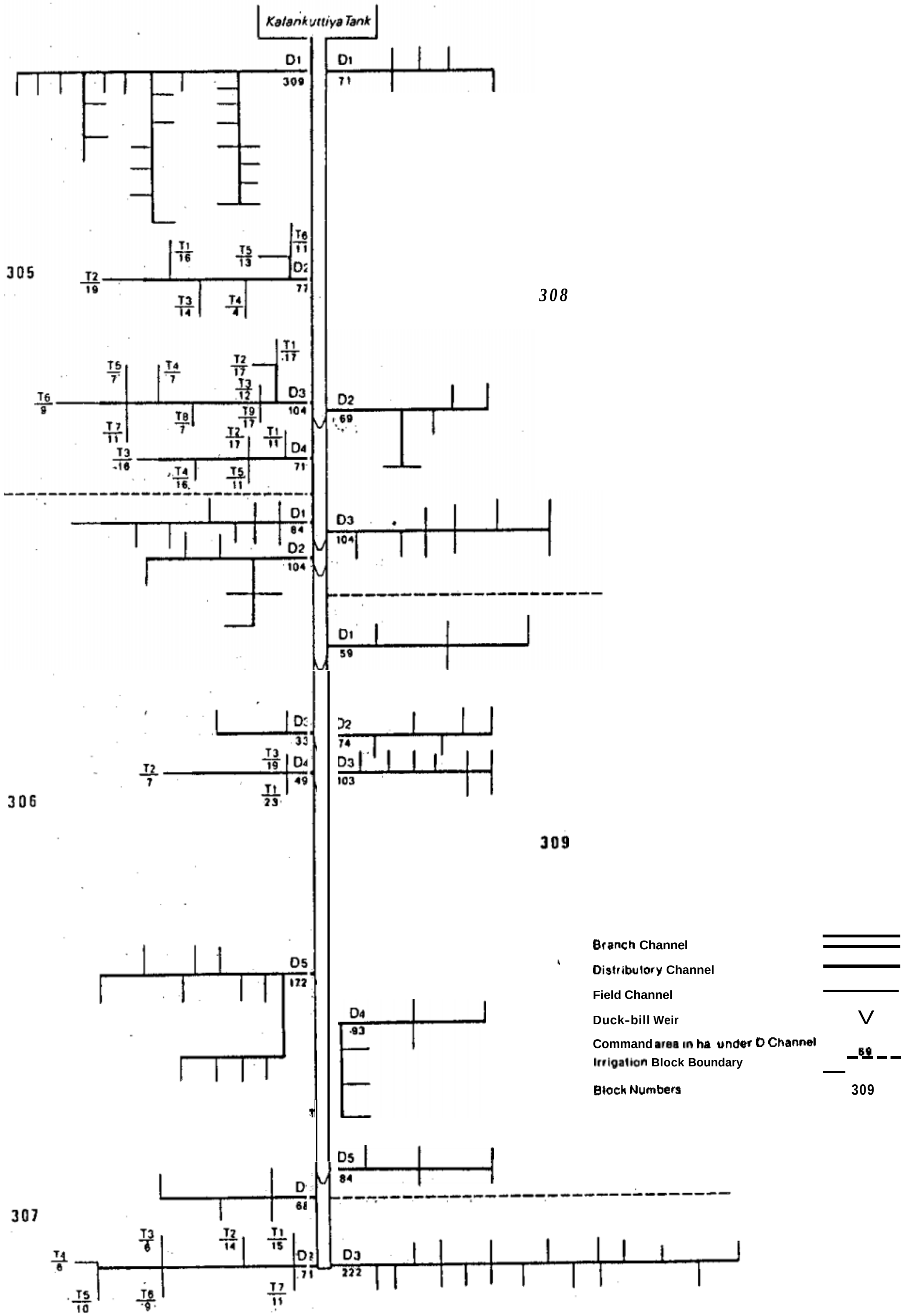


Figure II.14

Kalankuttiya branch canal

Maximum expected range of water level variation above offtake invert levels

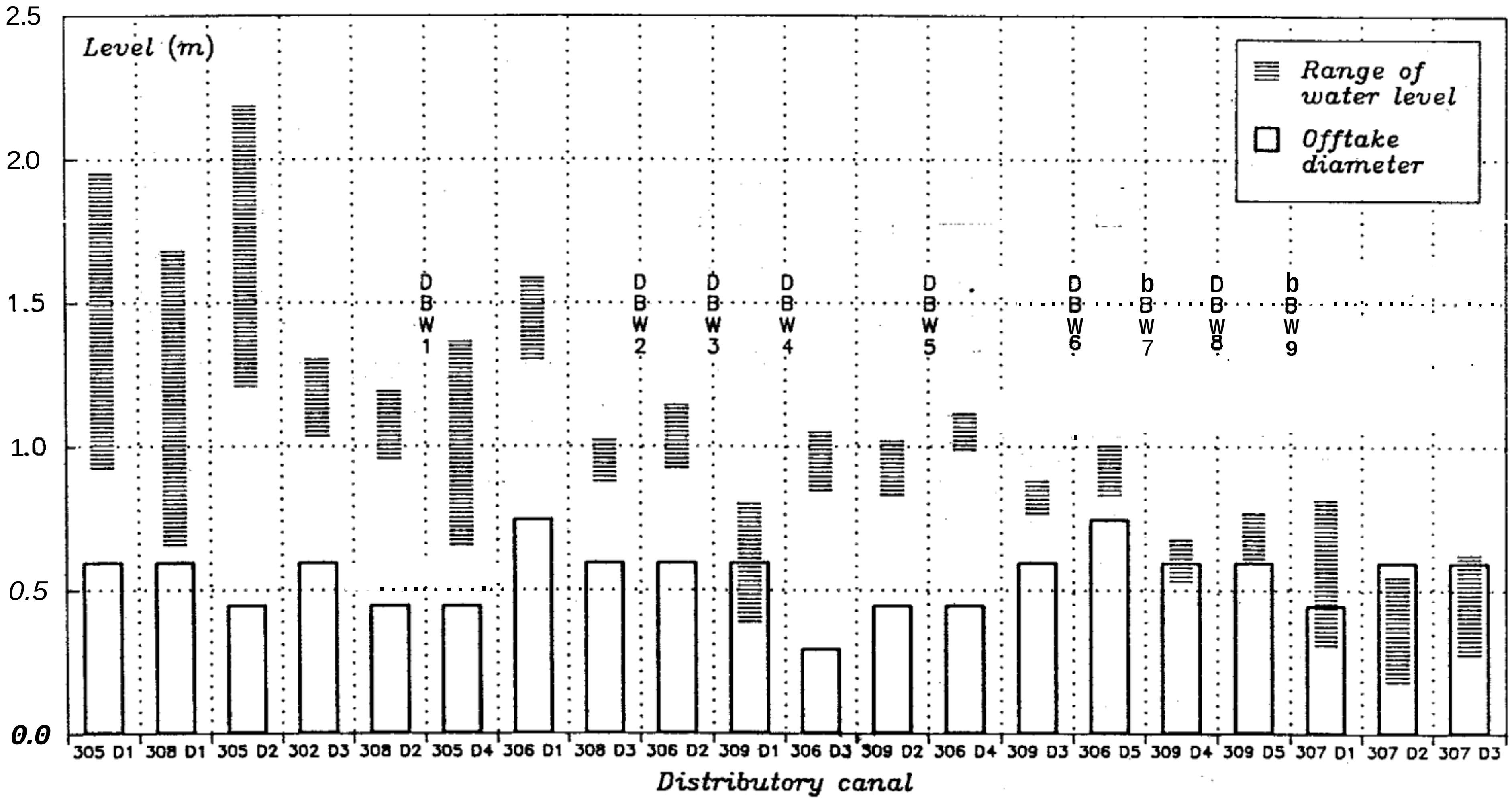


Figure II.15 Kalankuttiya branch canal: Comparison of simulated and observed relative range of water level variation at offtakes

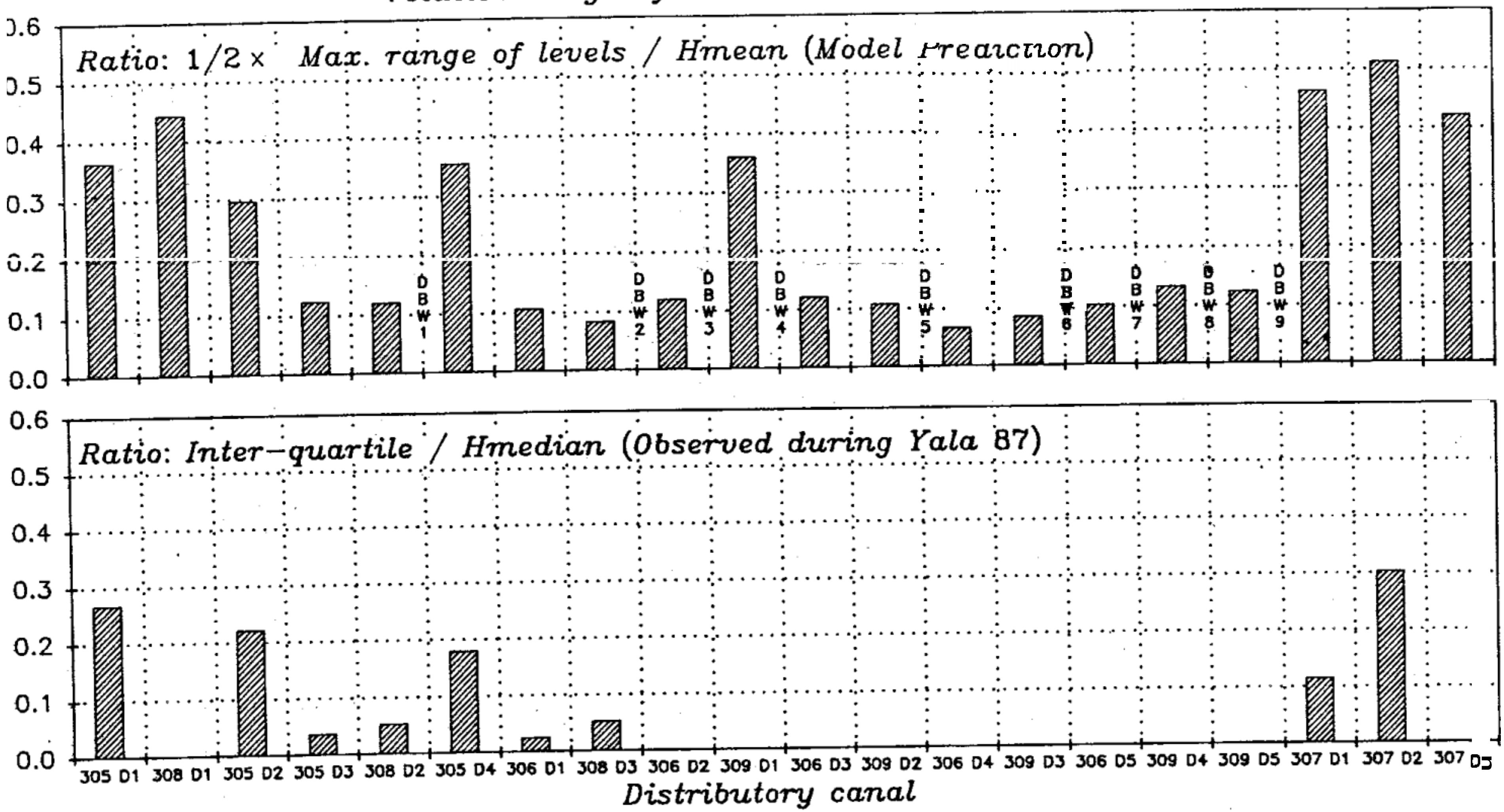


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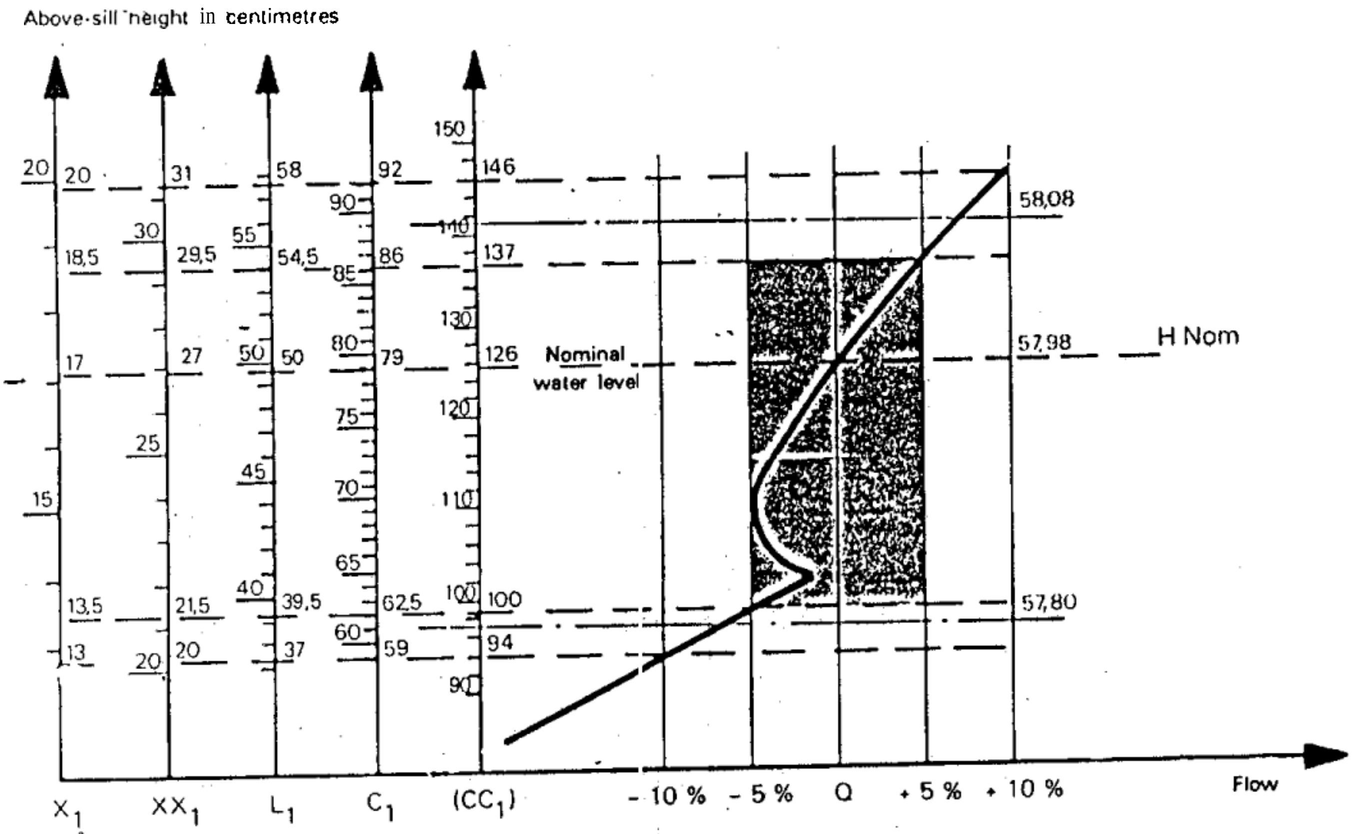
Figure II.17
Characteristic line of single baffle distributors



Note : some changes in the flow may result from the location of the unit in the works or from the relative positions of the shurrers closed and open. Therefore the flow/height characteristic curve must not be considered as a well defined lire but only as a middle-line of possible operating points however all situated within the normal tolerance zone of the distributor.

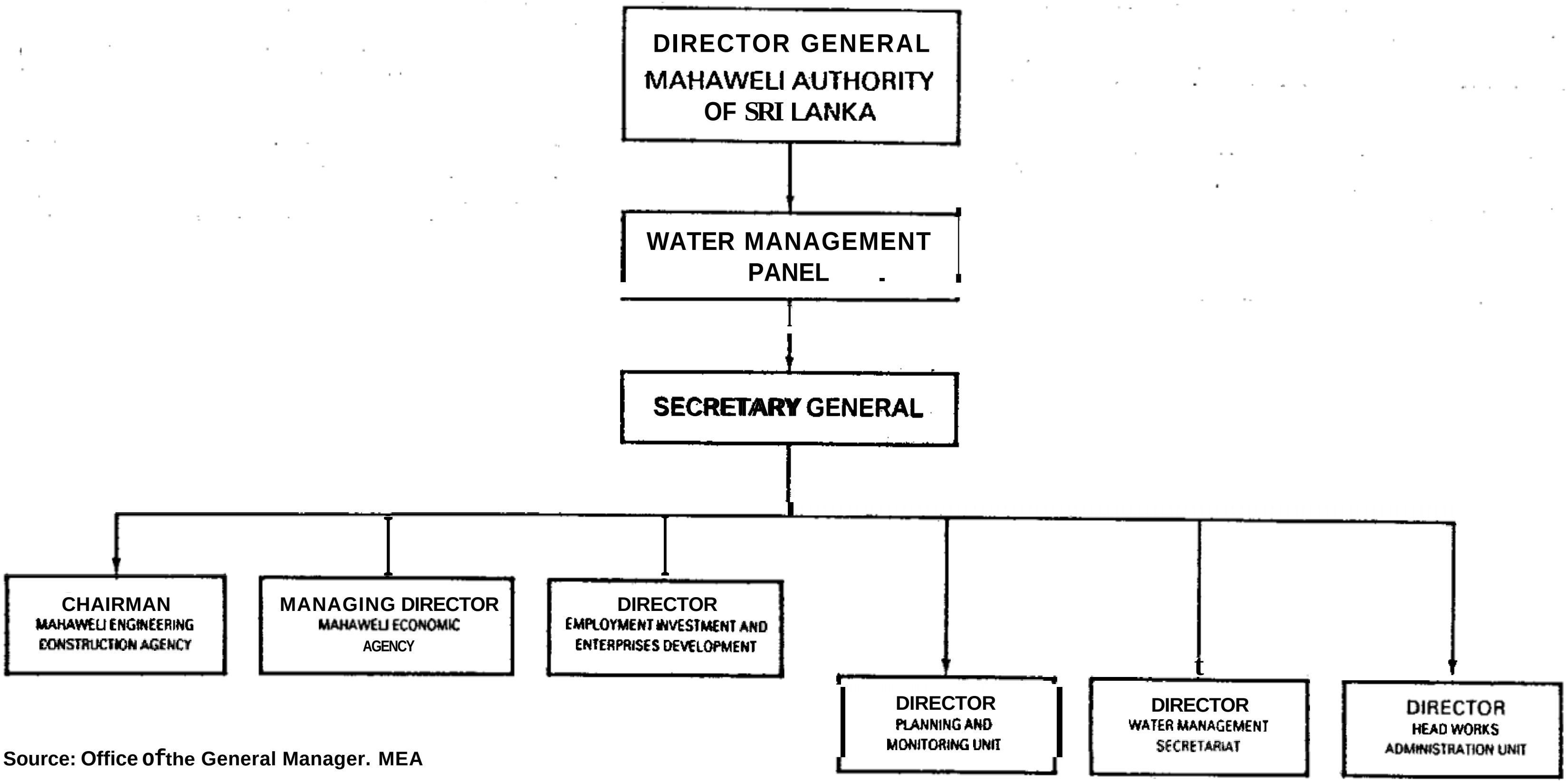
Head loss arid permissible level variations for the various types

Heights in centimetres

TYPE	Flow per unit sill width	H min. Q — 10 %	H' min. Q — 5 %	H nom. Q	H' max. Q + 5 %	H max. Q + 10 %	d H Q ± 10 %	d H' Q ± 5 %	J. min. for H nom.	J min. for H min.	P min. *
X_1	10 l/s/dm	13	13.5	17	18.5	20	7	5	6.5	5	16
XX_1	20 «	20	21.5	27	29.5	31	11	8	10.6	8	25
L_1	50 «	37	39.5	50	54.5	58	21	15	19	15	47
C_1	100 «	59	62.5	79	86	92	33	23.5	30	24	75
(CC_1)	200 «	94	100	126	137	146	52	37	48	38	118
X_2	10 l/s/dm	13	13.5	17.5	28	31	18	14.5	6.5	5	17
XX_2	20 «	20	21	28	44	48	28	23	11	8	26
L_2	50 «	37	39	51	82	89	52	43	20	15	49
C_2	100 «	59	62	81	130	142	83	68	31	24	77
(CC_2)	200 «	94	99	29	206	225	131	107	50	38	122

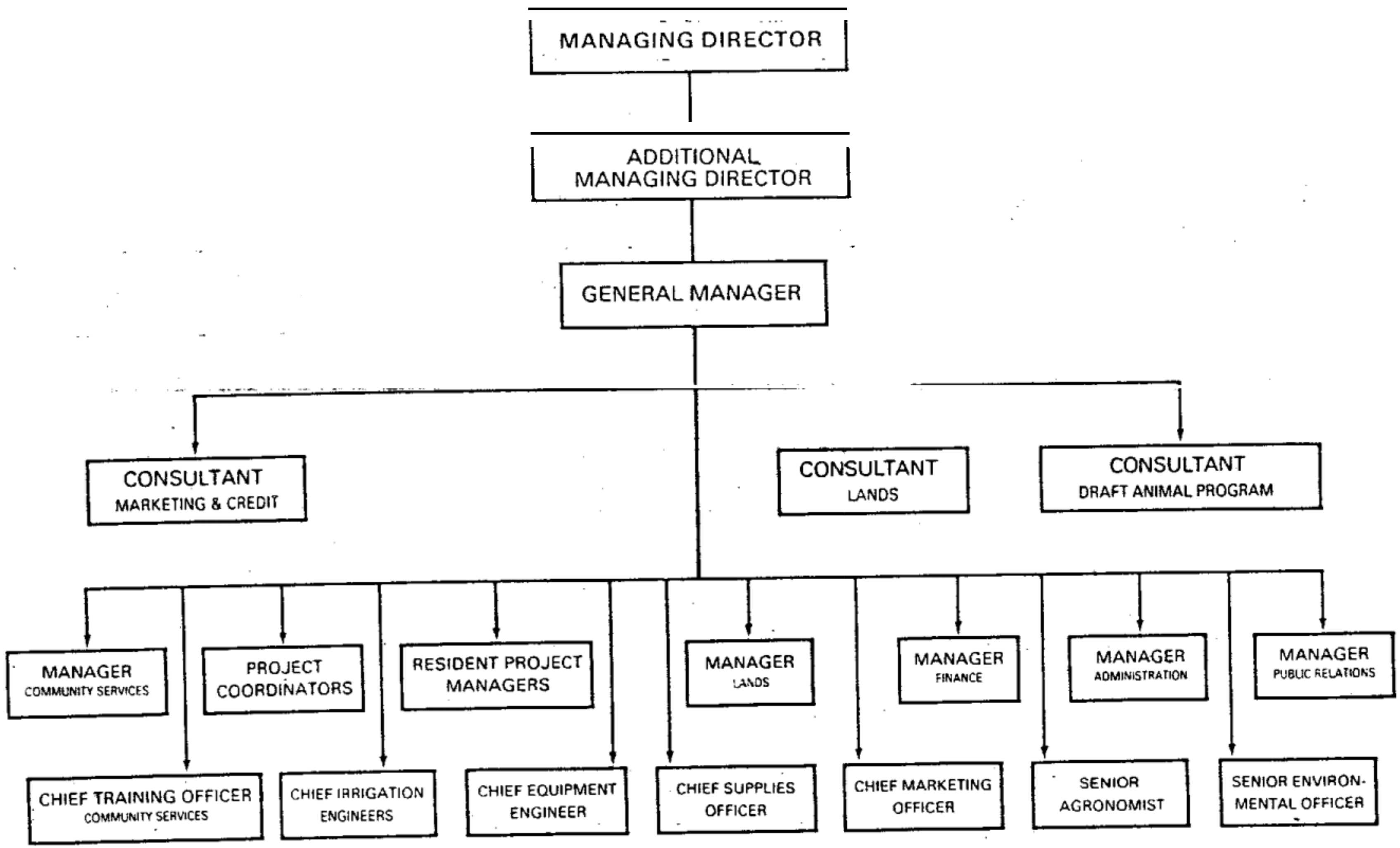
(*) P is the height of the sill above the upstream floor level (P = a — H nom

Figure 111.1   The Mahaweli Organization



Source: Office of the General Manager. MEA

Figure III.2 The Mahaweli Economic Agency



Source: Office of the General Manager, MEA

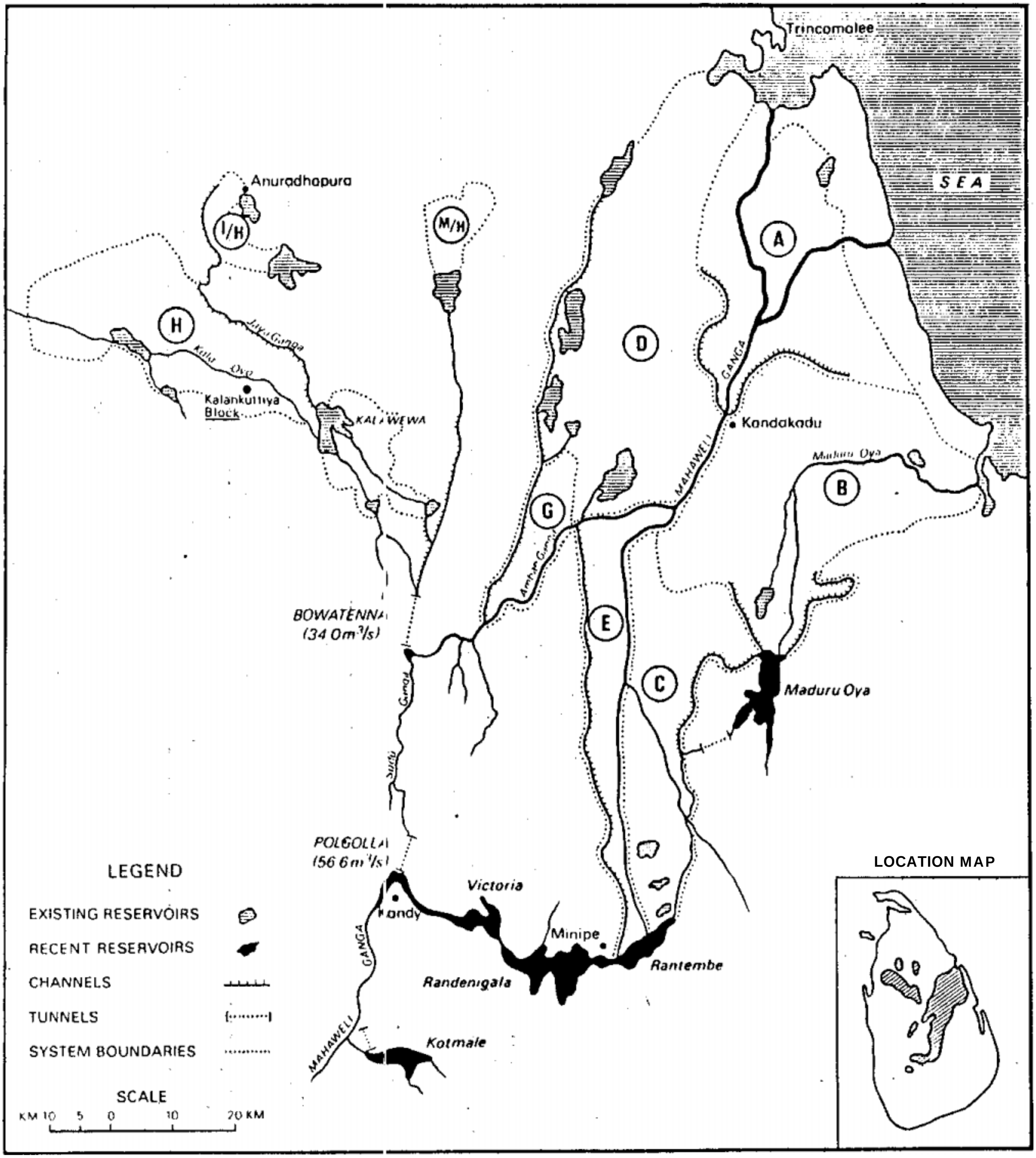
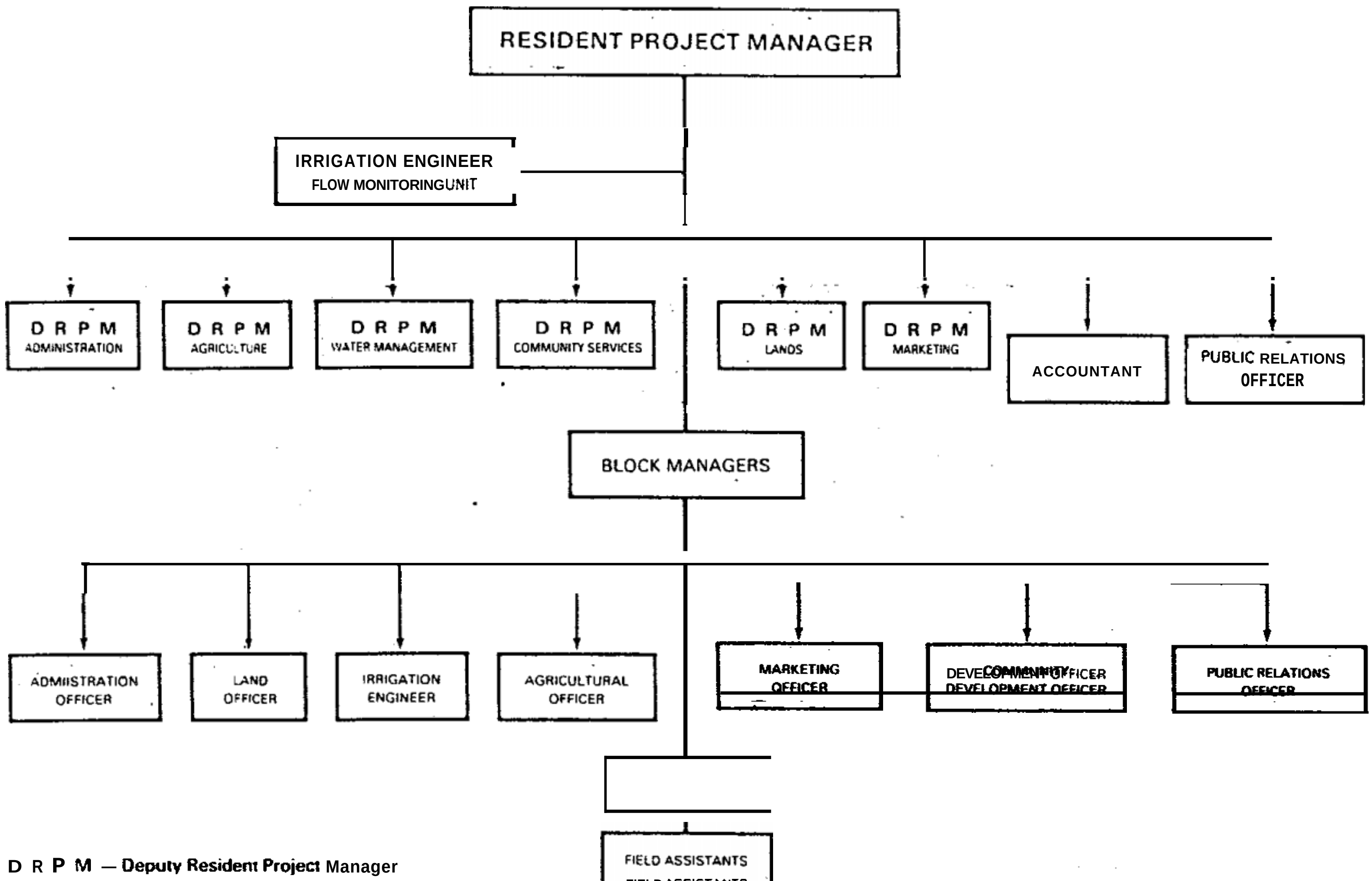

Trincomalee
SEA
Anuradhapura
I/H
M/H
A
H
D
Jaya Ganga
Kala Oya
Kalankuttiya
Block
KALAWEWA
GANGA
Kandakadu
MAHAWELI
Maduru Oya
B
G
Amban Ganga
BOWATENNA
(34.0m³/s)
E
C
Maduru Oya
Sudu Ganga
POLGOLLA
(56.6m³/s)
Victoria
Kandy
Minipe
Rantembe
Randenigala
GANGA
MAHAWELI
Kotmale
LEGEND
EXISTING RESERVOIRS
RECENT RESERVOIRS
CHANNELS
TUNNELS
SYSTEM BOUNDARIES
SCALE
KM 10 5 0 10 20 KM
LOCATION MAP

Figure III.4 Project Level Organization – Mahaweli Economic Agency

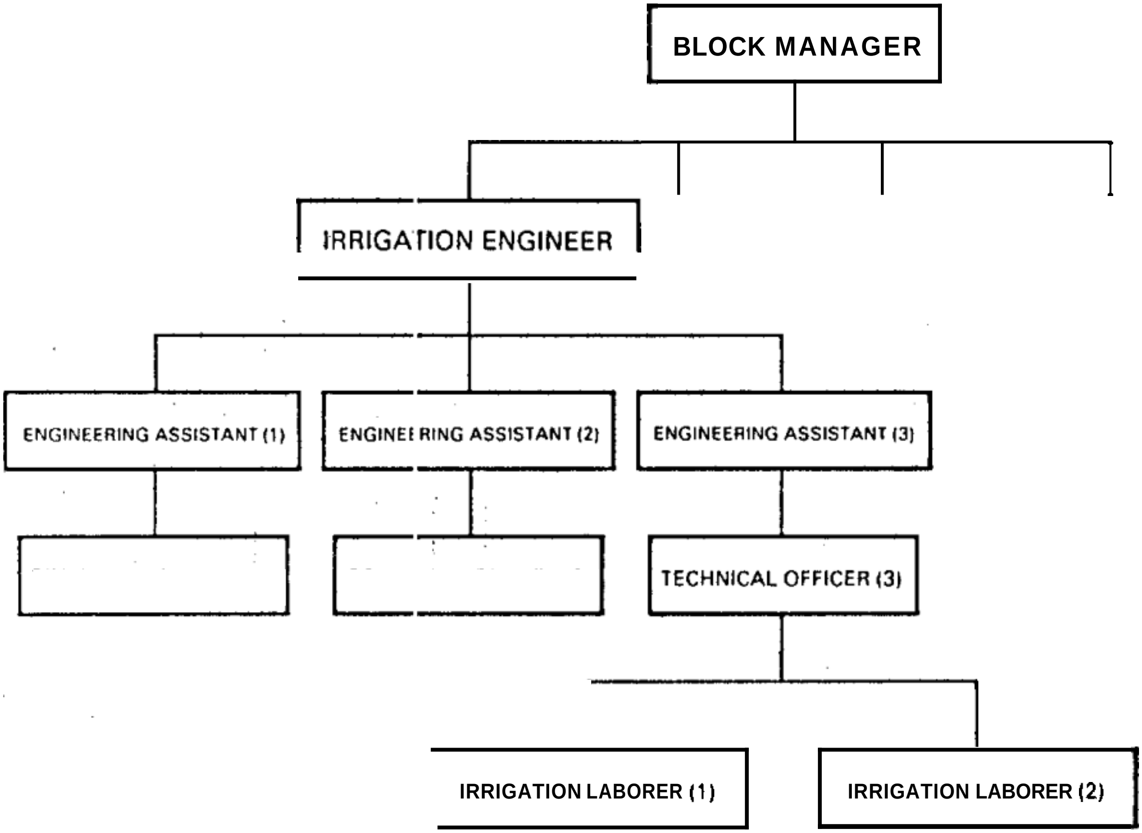


D R P M — Deputy Resident Project Manager

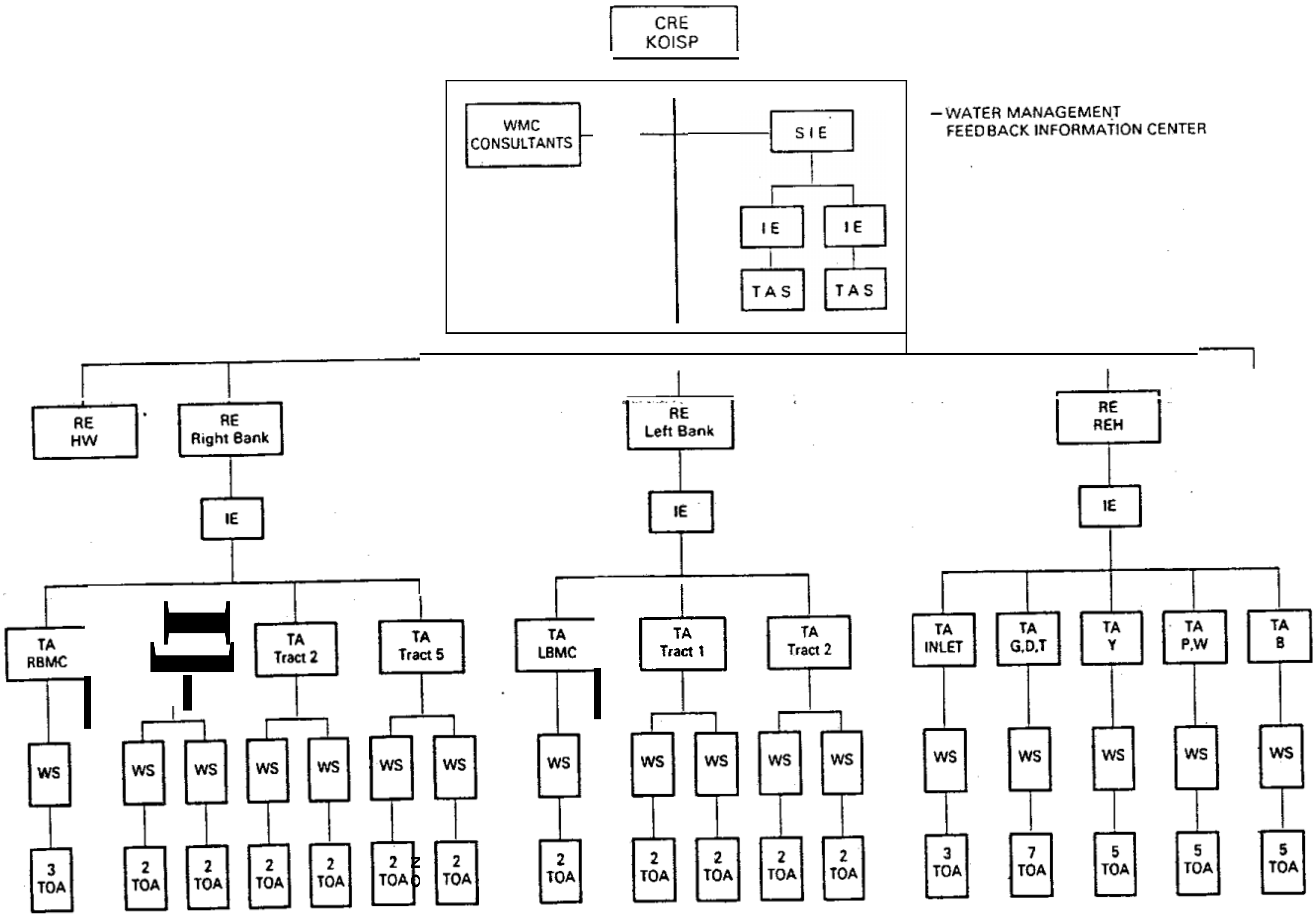
Source Office of rhe General Manager. MEA

Note: Galnewa Project has no DRPM for Administration or Marketing. This is an idealized diagram

Figure III.5 **Organization for Irrigation Control in Kalankuttiya Block**



Fi 111.6 Chart of KOISP O&M



INLET - Wewa supply system Ellagala area

Figure 111.7 NIA/UPRIIS Organisational Chart

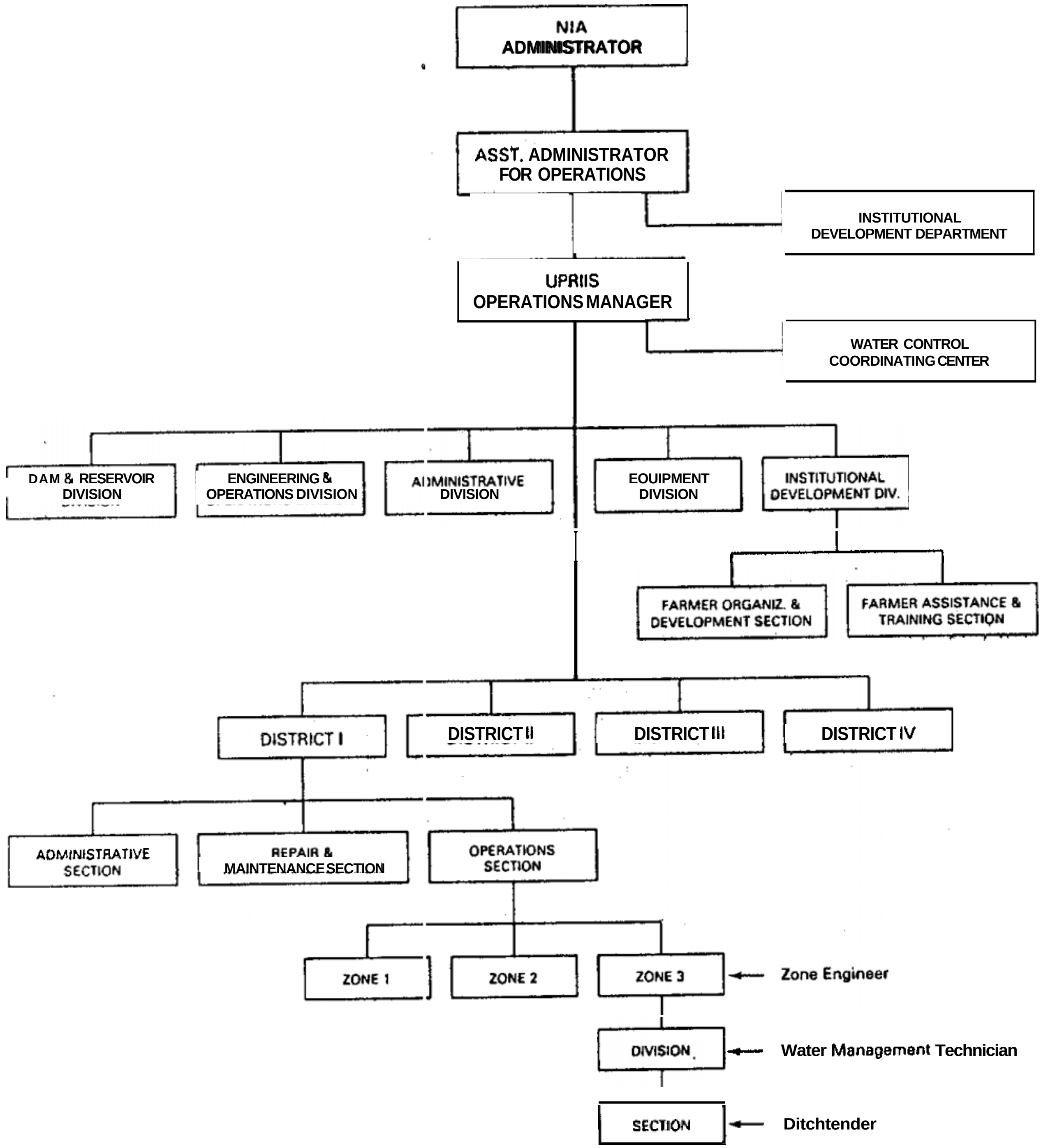


Figure 111.8 Organization Chart for District 1 (25,341 ha)

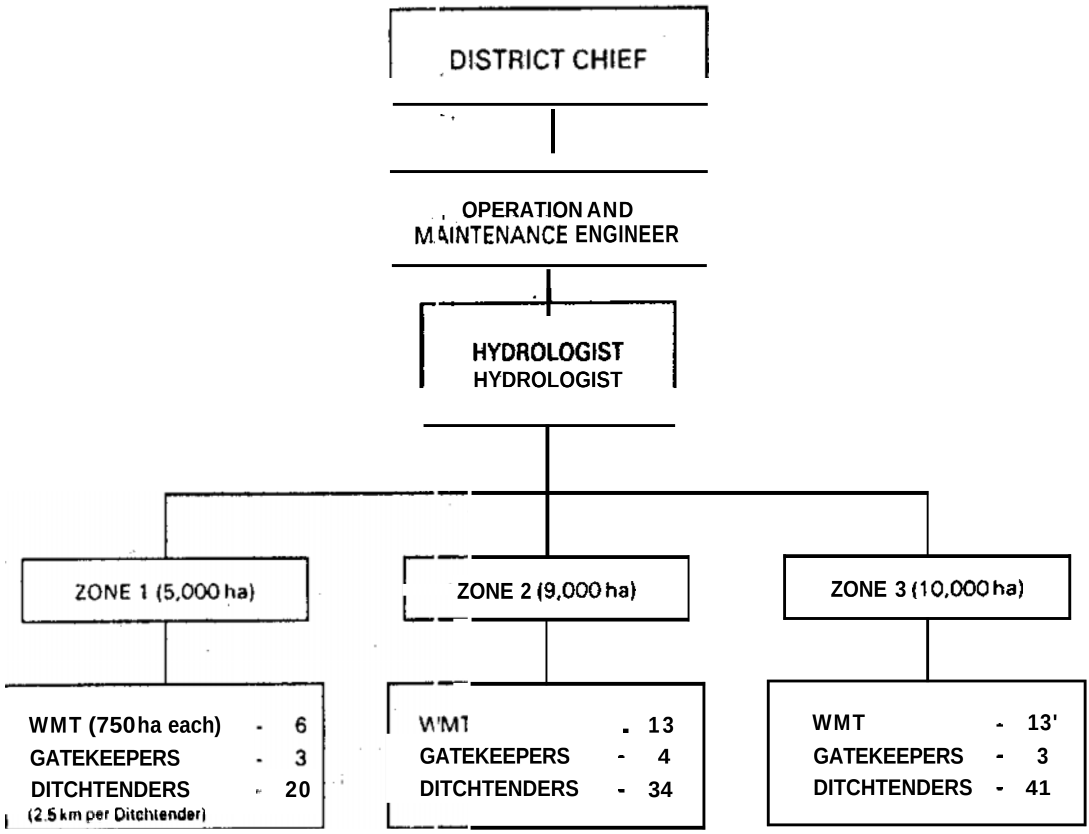


Figure III.9 Control of water resources

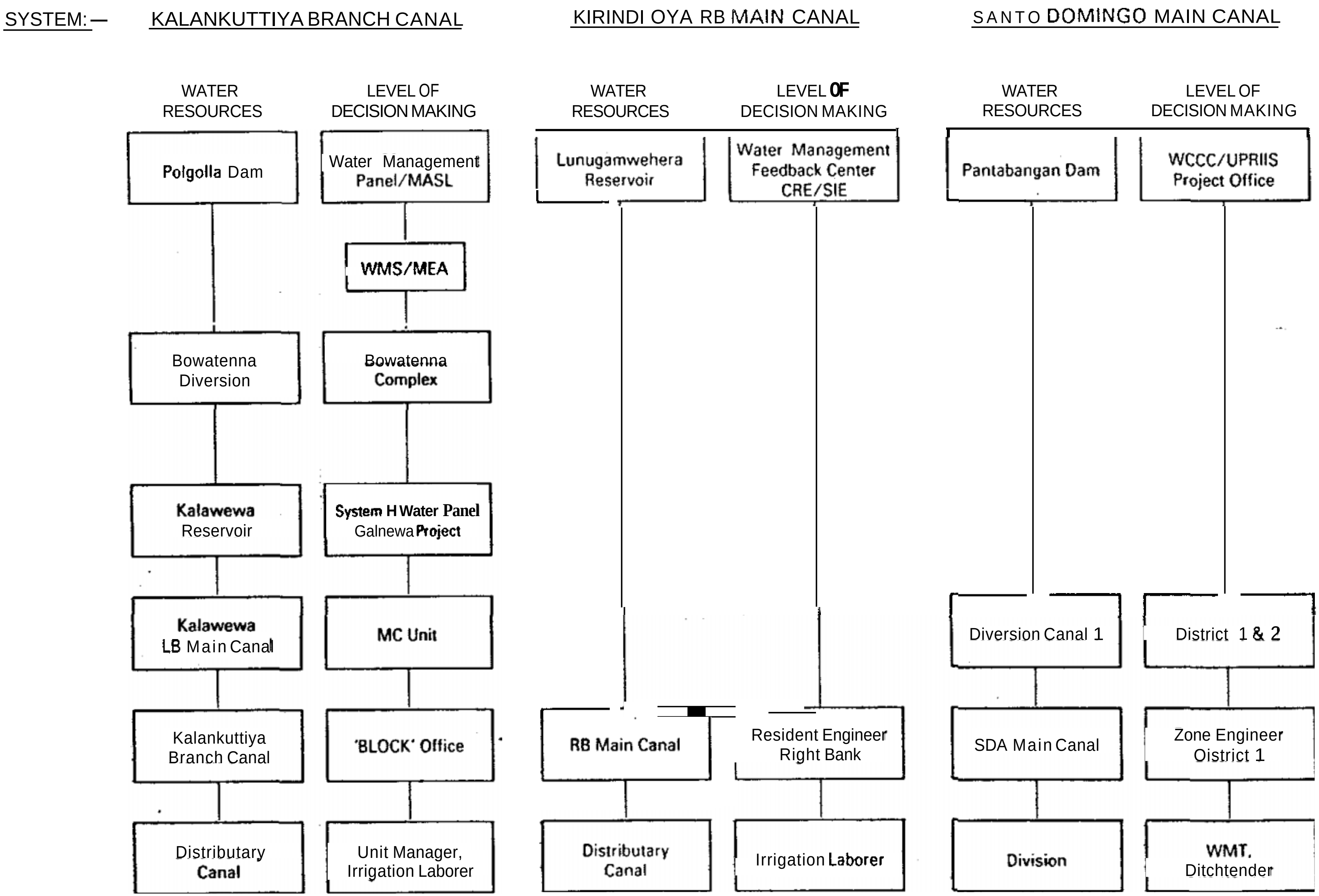
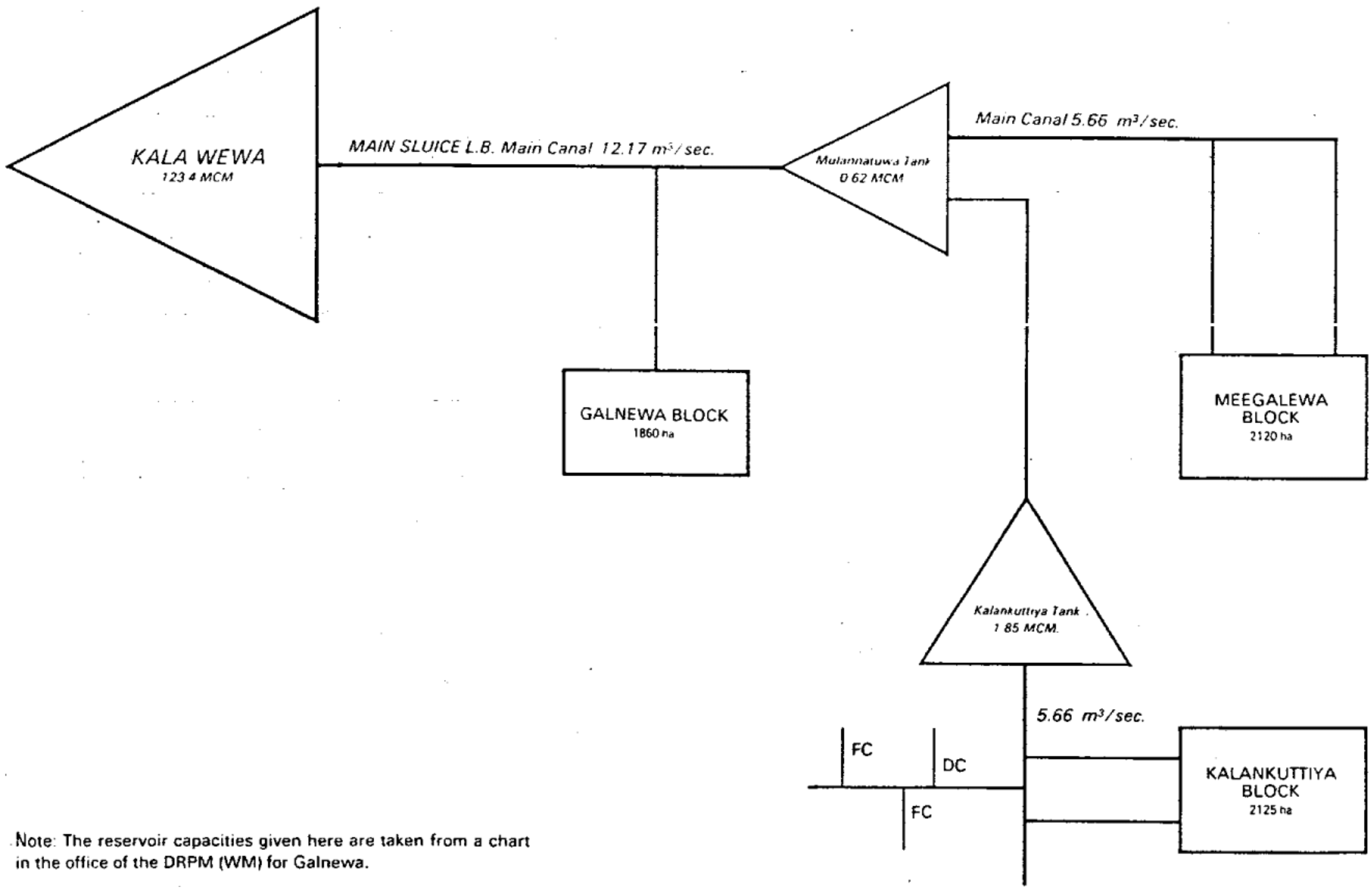


Figure III 10 Water Delivery System (Kalawewa L B Main Canal Kalankuttiya Branch Canal)



Note: The reservoir capacities given here are taken from a chart in the office of the DRPM (WM) for Galnewa.

Figure III.11 Comparison of Density of Management in three systems studied

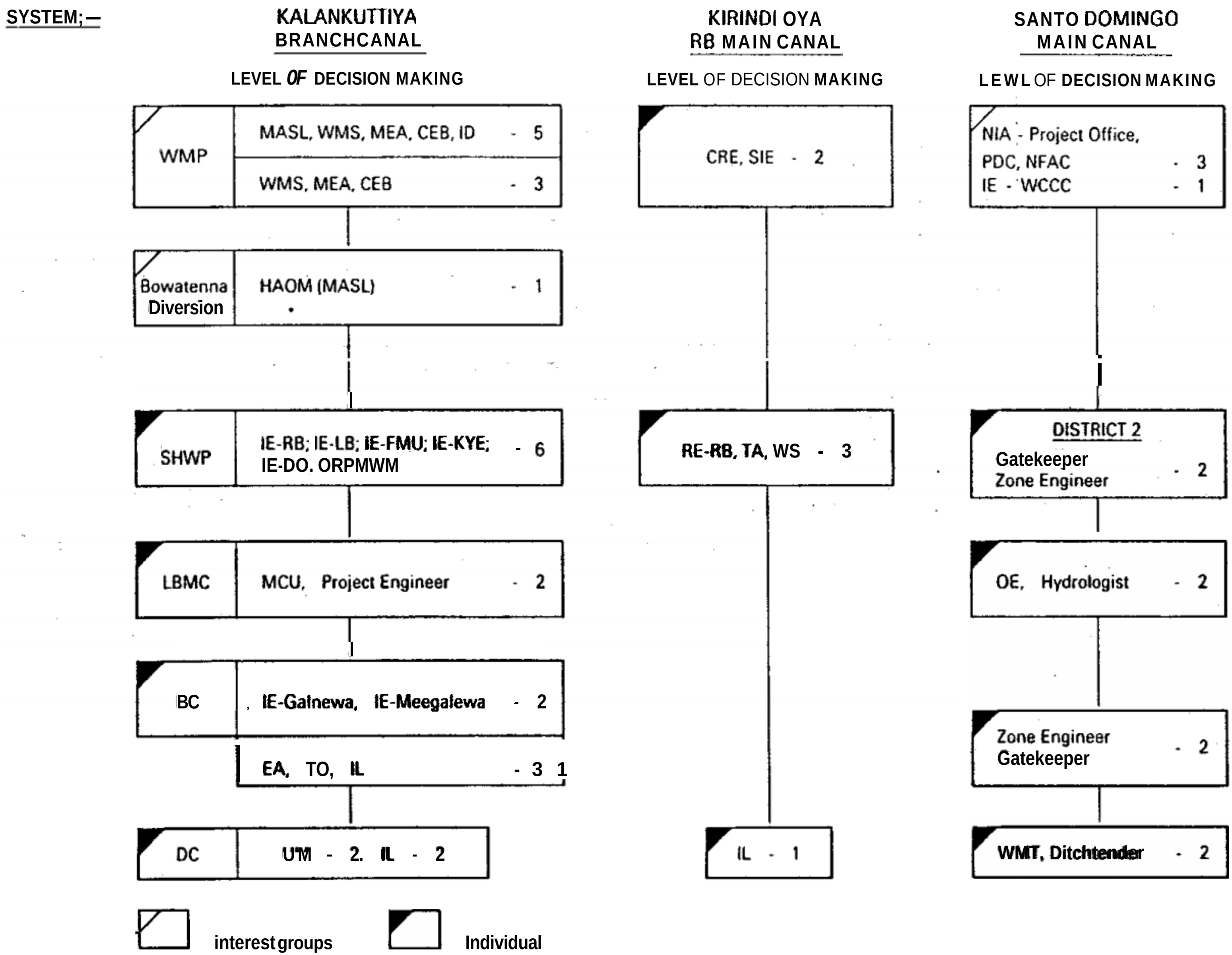
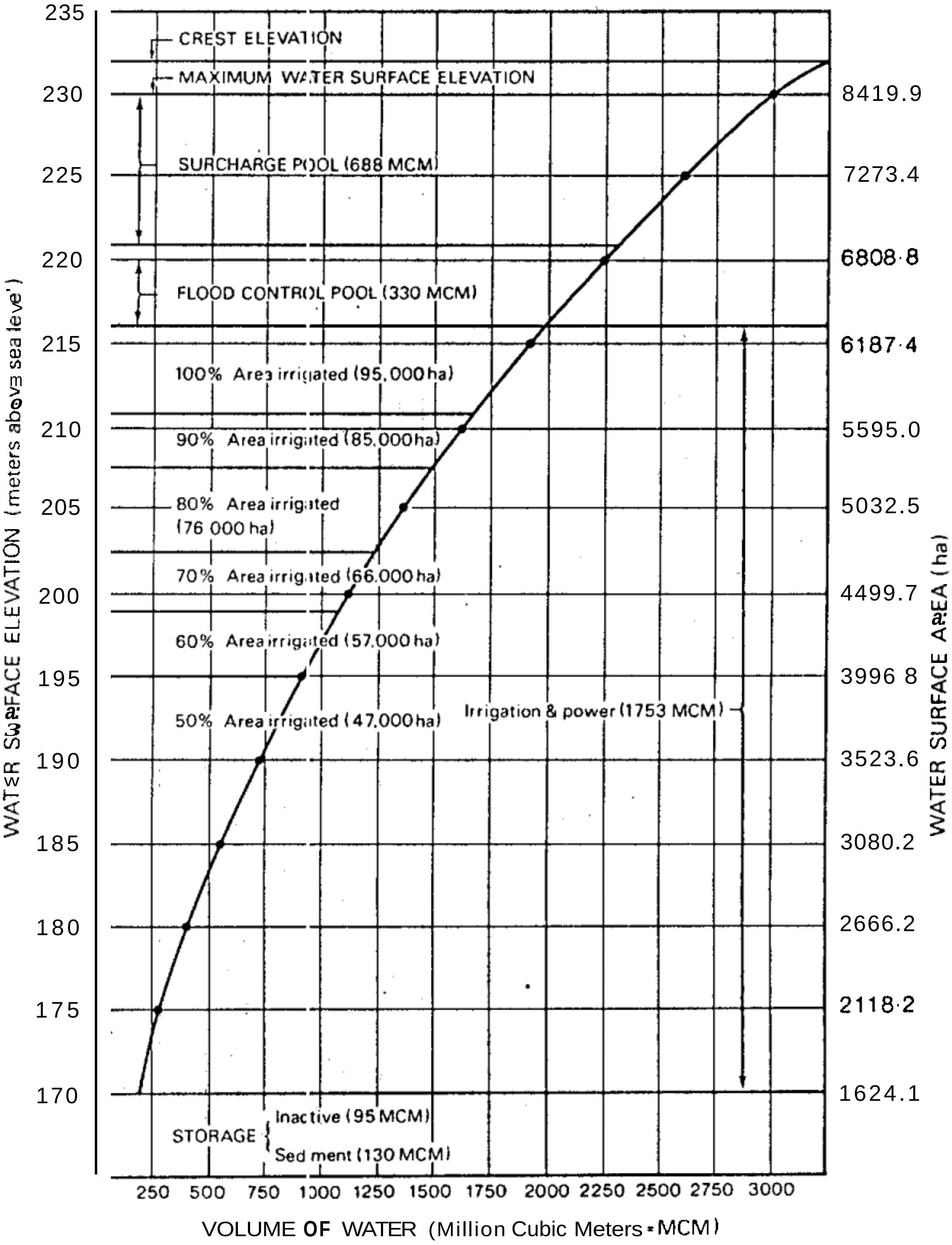


Figure 111.12 **UPRILS** Operation rule **curve**

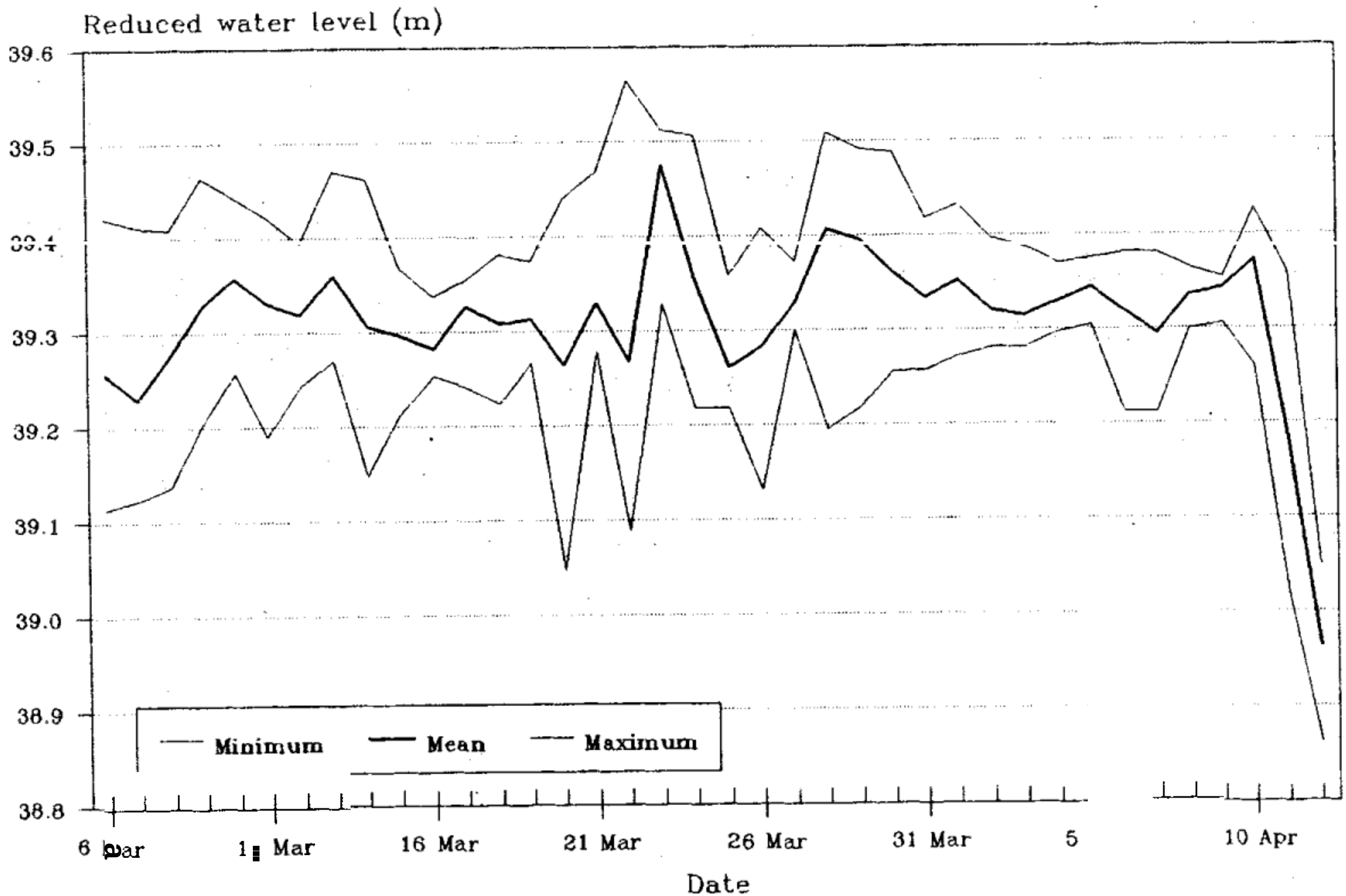


RESERVOIR FILLING RULE CURVE

01 May . 15 Sept. Increase elevation to 216.0 m
16 Sept. - 15 Oct. Increase elevation from 216.0 m to 218.5 m
16 Oct . 30 Dec. Constant at 221.0 m

Note: Dry season operation rule curve computed with 36% farm efficiency and 31% project efficiency.

Figure IV.1 Kirindi Oya: Daily range of water level variation in the main canal near BC2 06 March to 12 April 1988



IV 2 Kirindi Oya Right Bank Main Canal System: calendar
December 1987 to July 1988

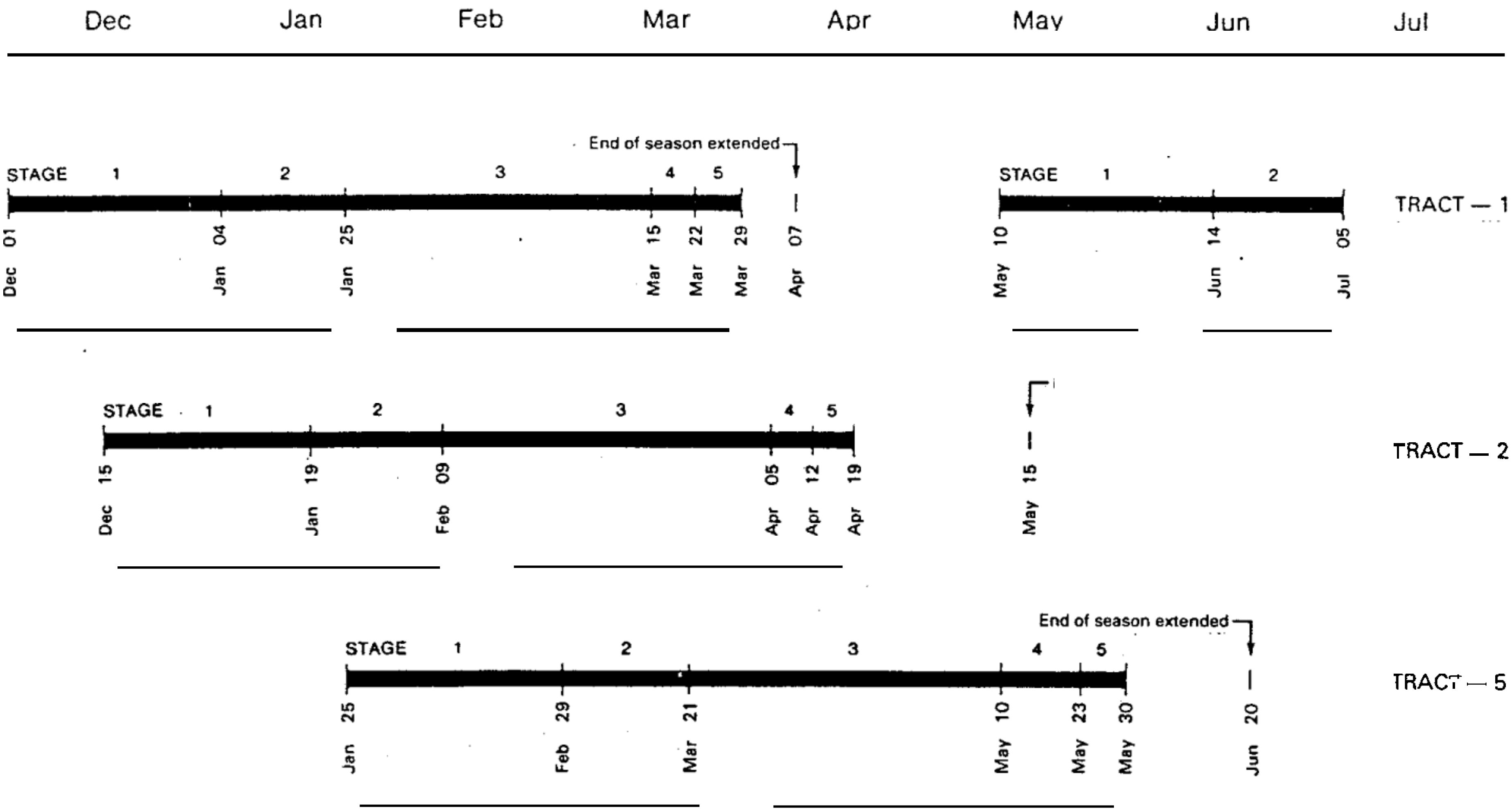


Figure IV.3

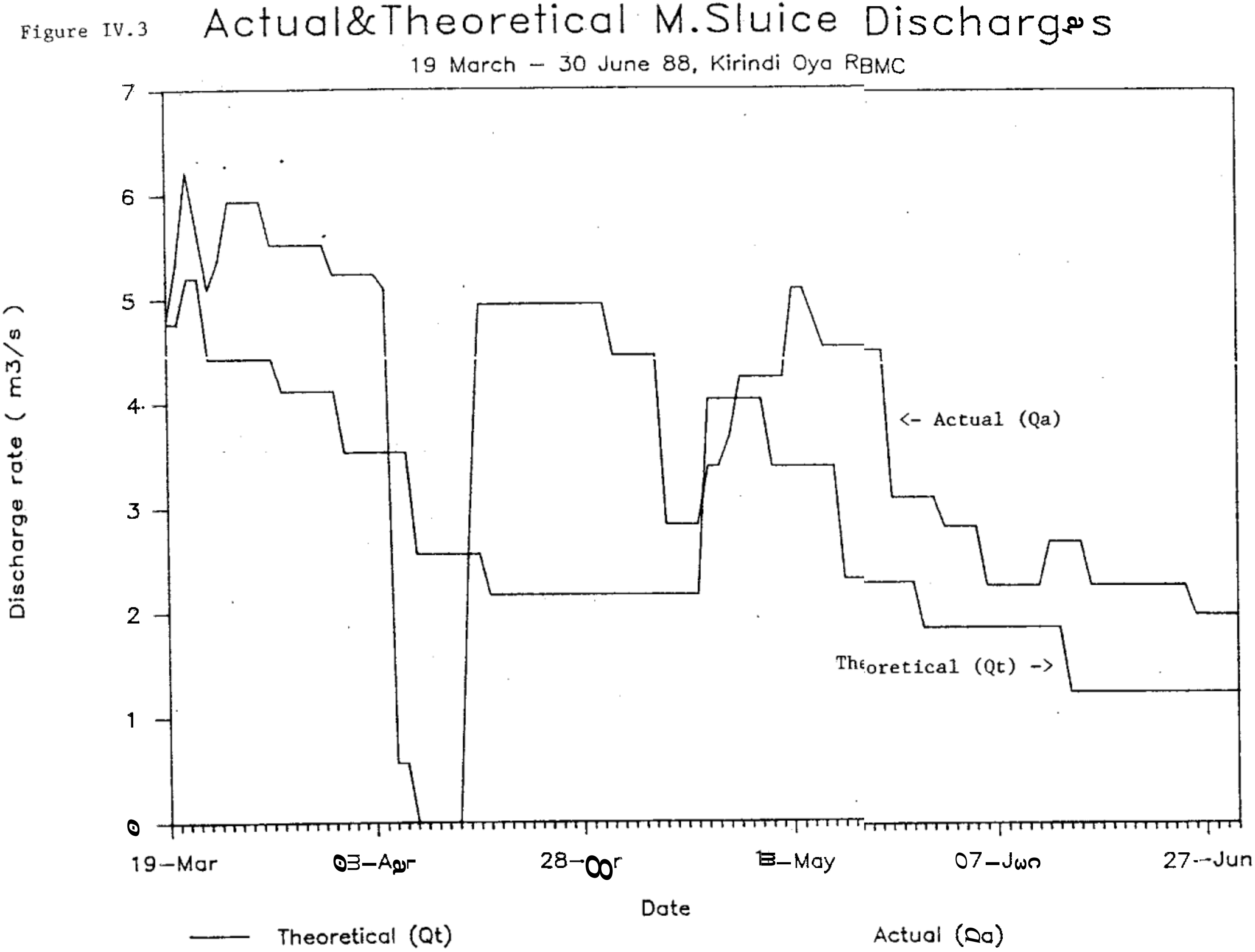
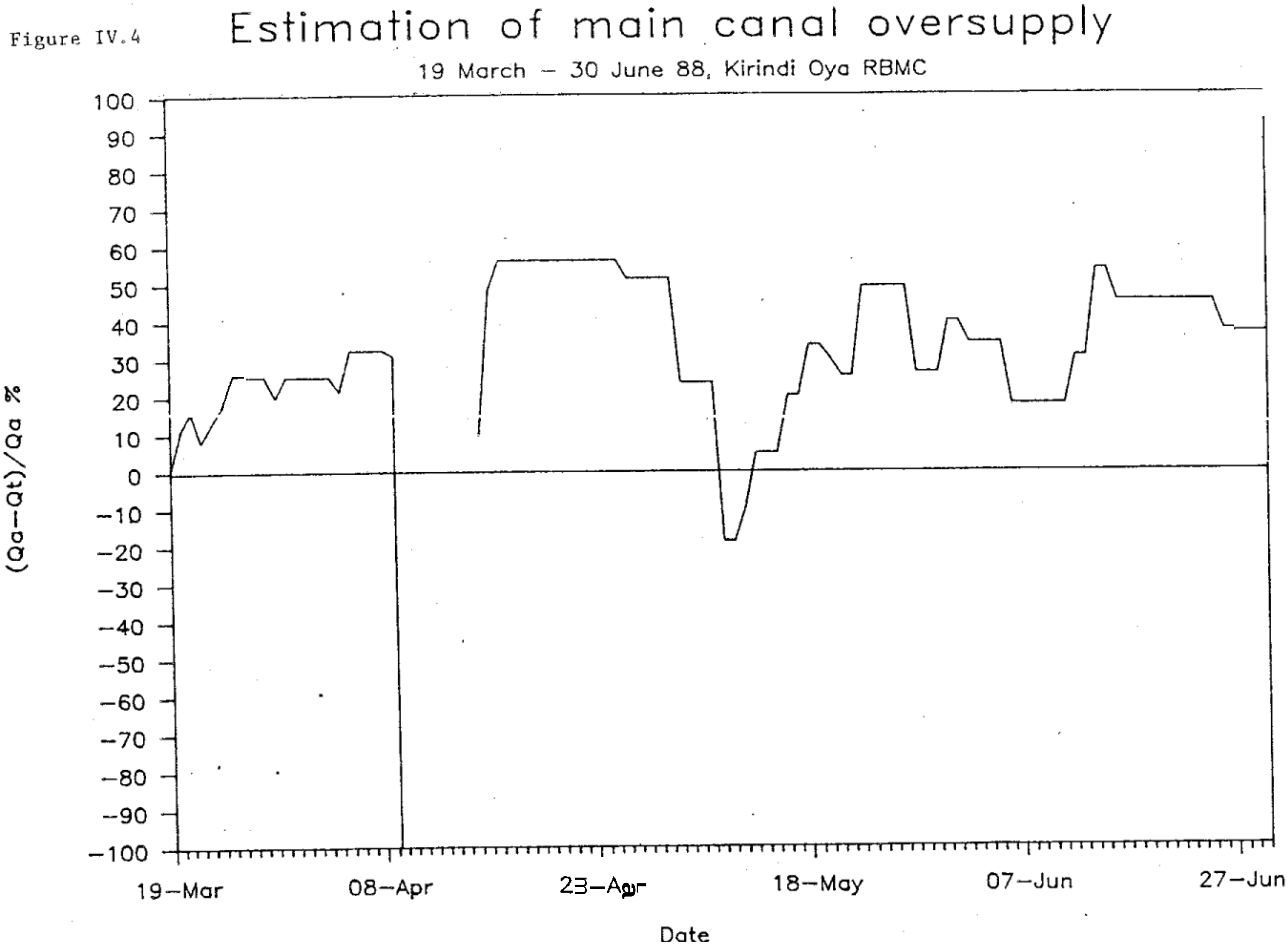

Actual&Theoretical M.Sluice Discharges
19 March – 30 June 88, Kirindi Oya RBMC
Discharge rate (m3/s)
7
6
5
4
3
2
1
0
19–Mar
03–Apr
28–Apr
18–May
07–Jun
27–Jun
Date
<- Actual (Qa)
Theoretical (Qt) ->
Theoretical (Qt)
Actual (Qa)

Figure IV.4



Estimation of main canal oversupply
19 March – 30 June 88, Kirindi Oya RBMC
100
90
80
70
60
50
40
30
20
10
0
–10
–20
–30
–40
–50
–60
–70
–80
–90
–100
(Qa–Qt)/Qa %
19–Mar
08–Apr
23–Apr
18–May
07–Jun
27–Jun
Date

Figure IV 5

Kirindi Oya: spatial variation of daily rainfall between Lunugamwehera and Wirawila (19[illegible])

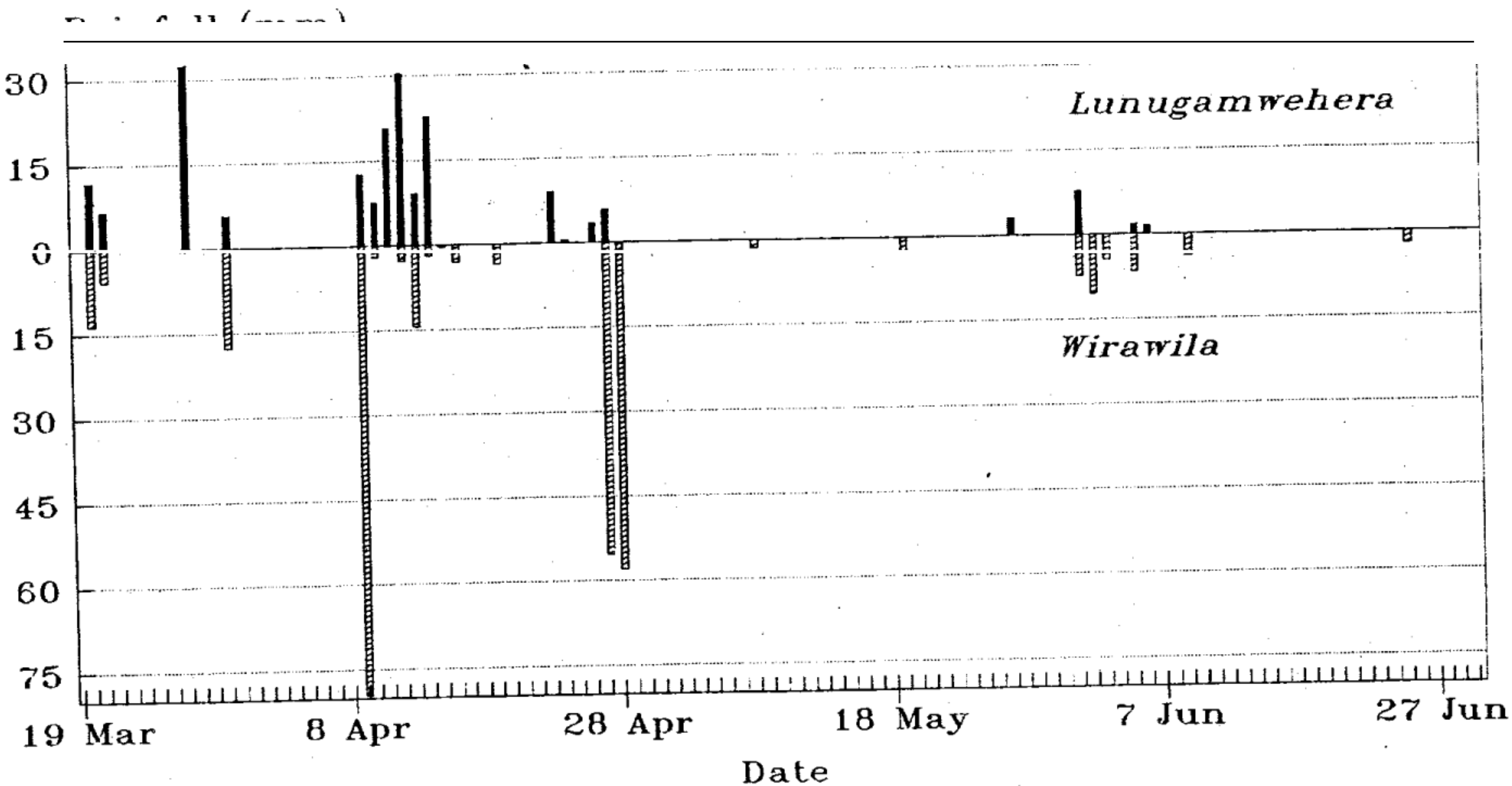
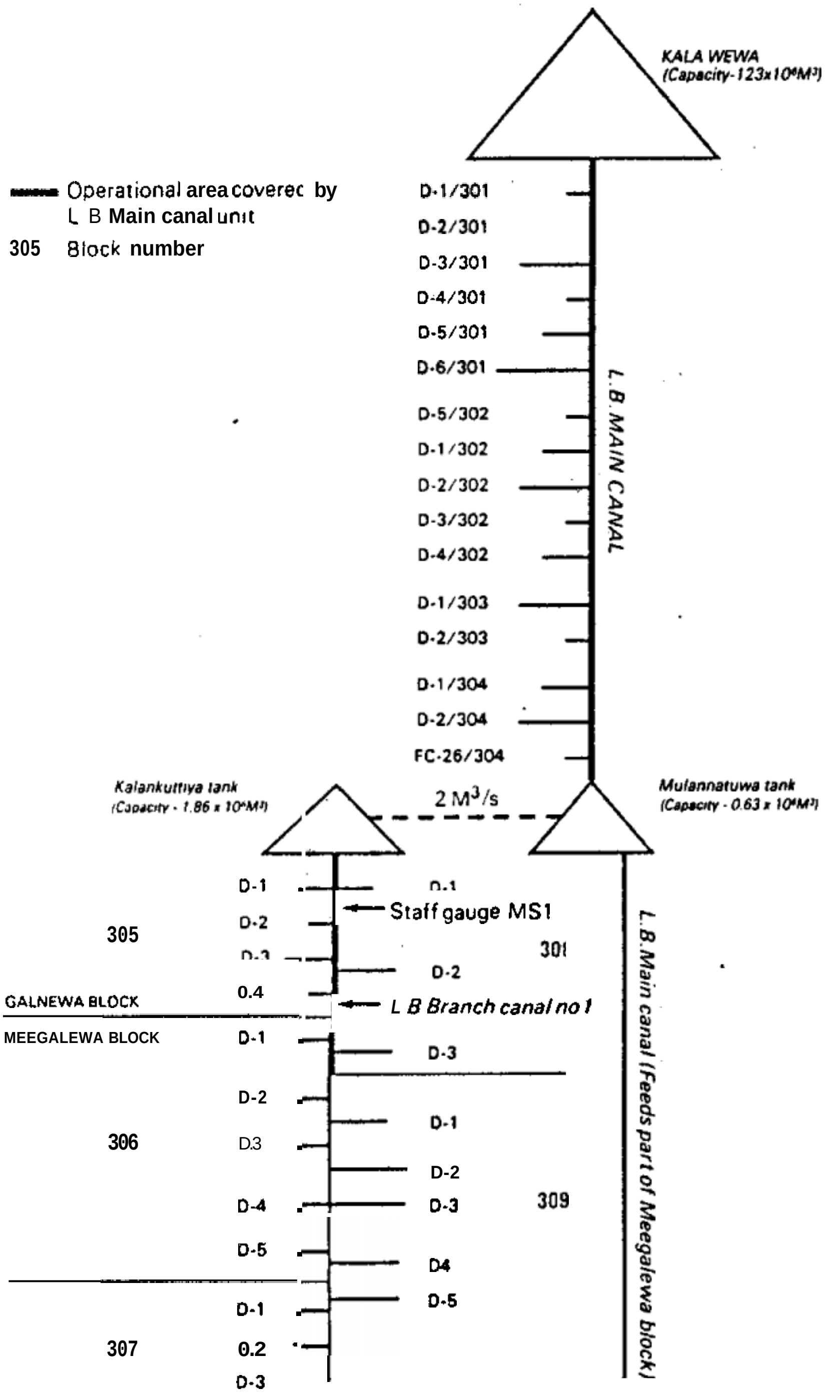
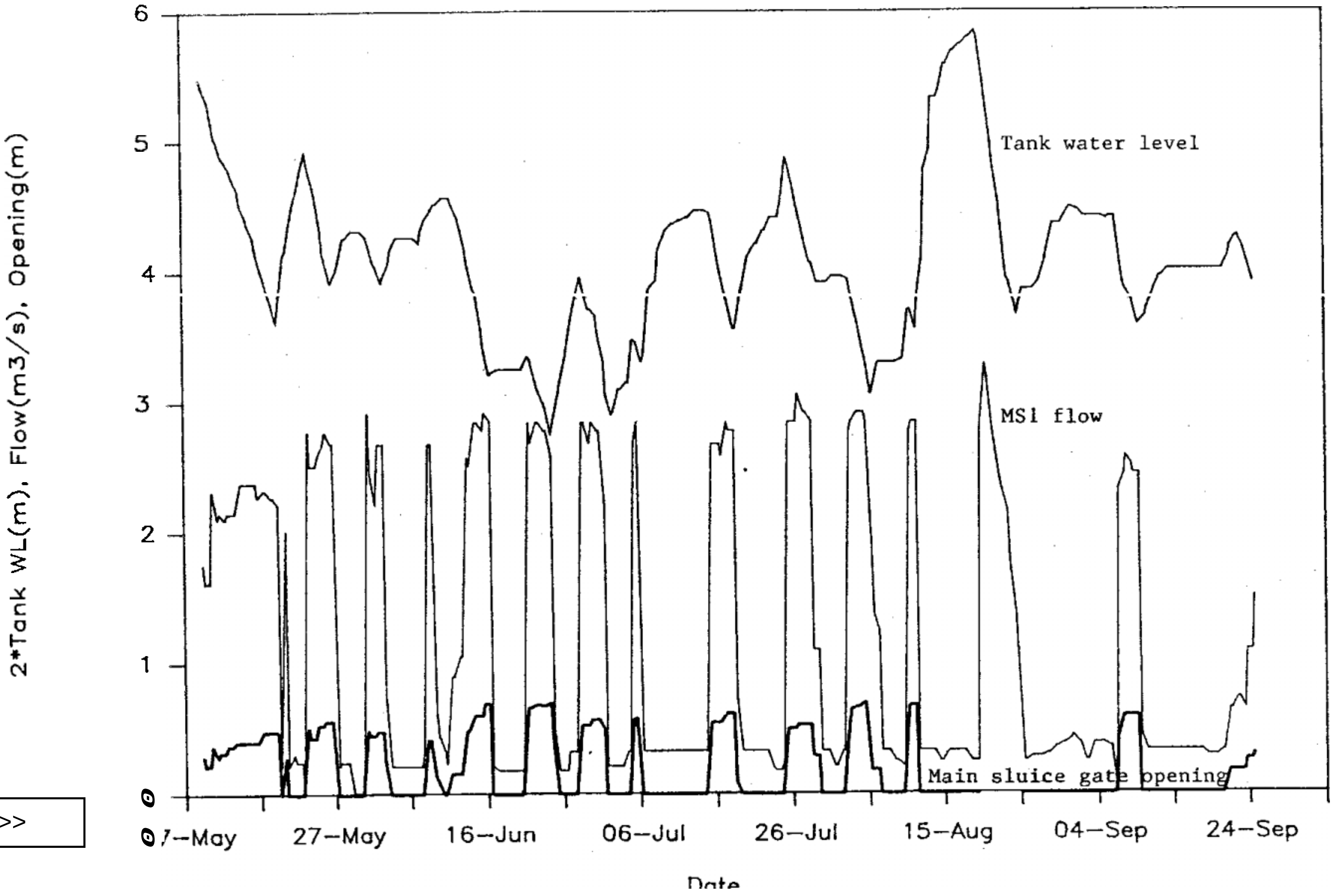


Figure 1V.6 Schematic layout of Kalawewa Left Bank Main Canal



Note After the recent reorganization, the project area has been divided into two administrative block areas, Galnewa and Meegalewa

Figure IV.7 Record of Tank water levels, Main sluice gate opening and Average daily discharge in branch canal measured at MS1, Kalankuttiya, Yala 1988



F-35

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Figure IV.8 Actual and planned daily water delivery near the head (at MS1) of Kalankuttiya branch canal in Yala 1988
Delivery expressed in terms of mean discharge

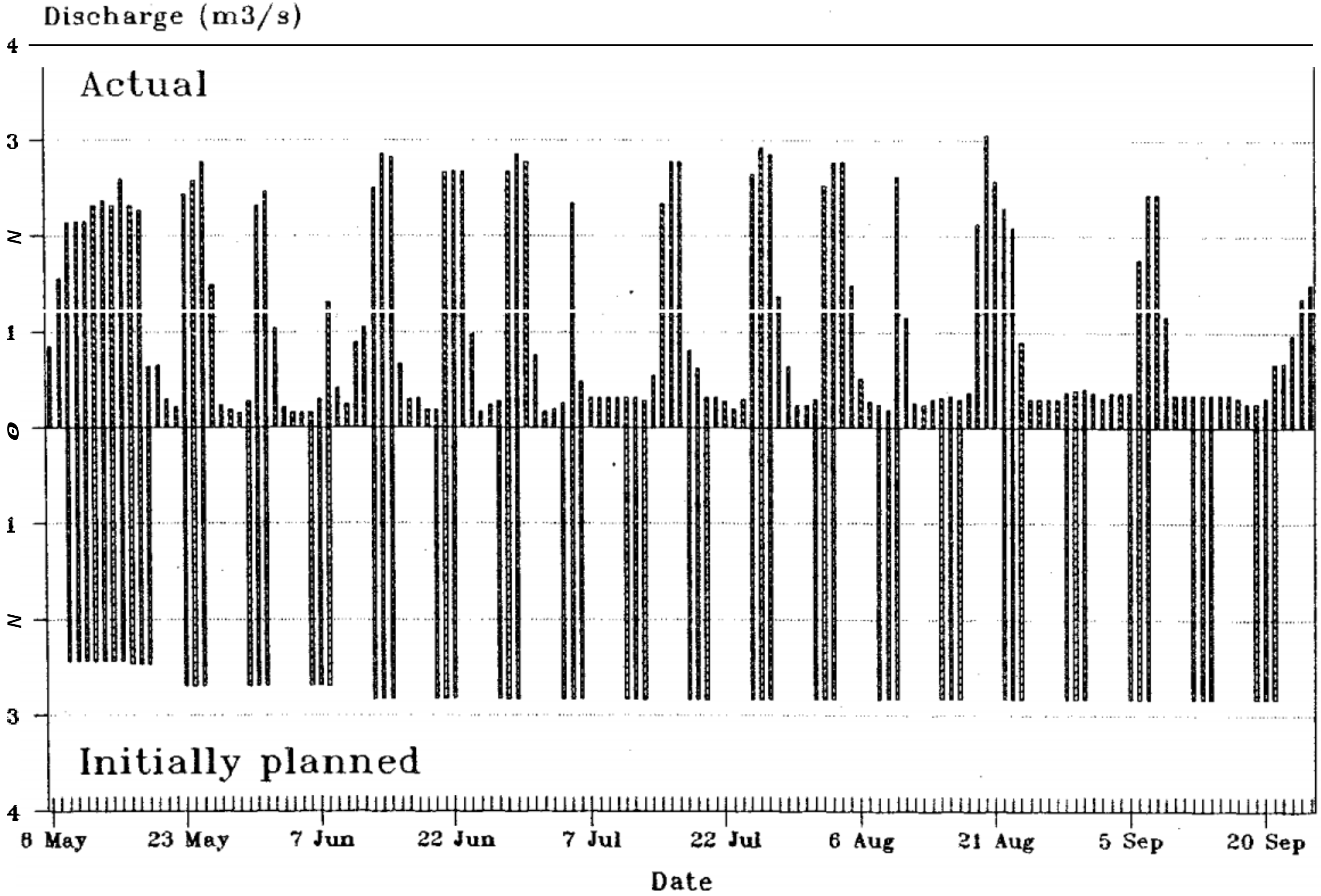


Figure IV.9 Actual and planned daily water delivery near the head (at MS1) of Kalankuttiya branch canal in Yala 1988

Delivery expressed in terms of depth over the cultivated area

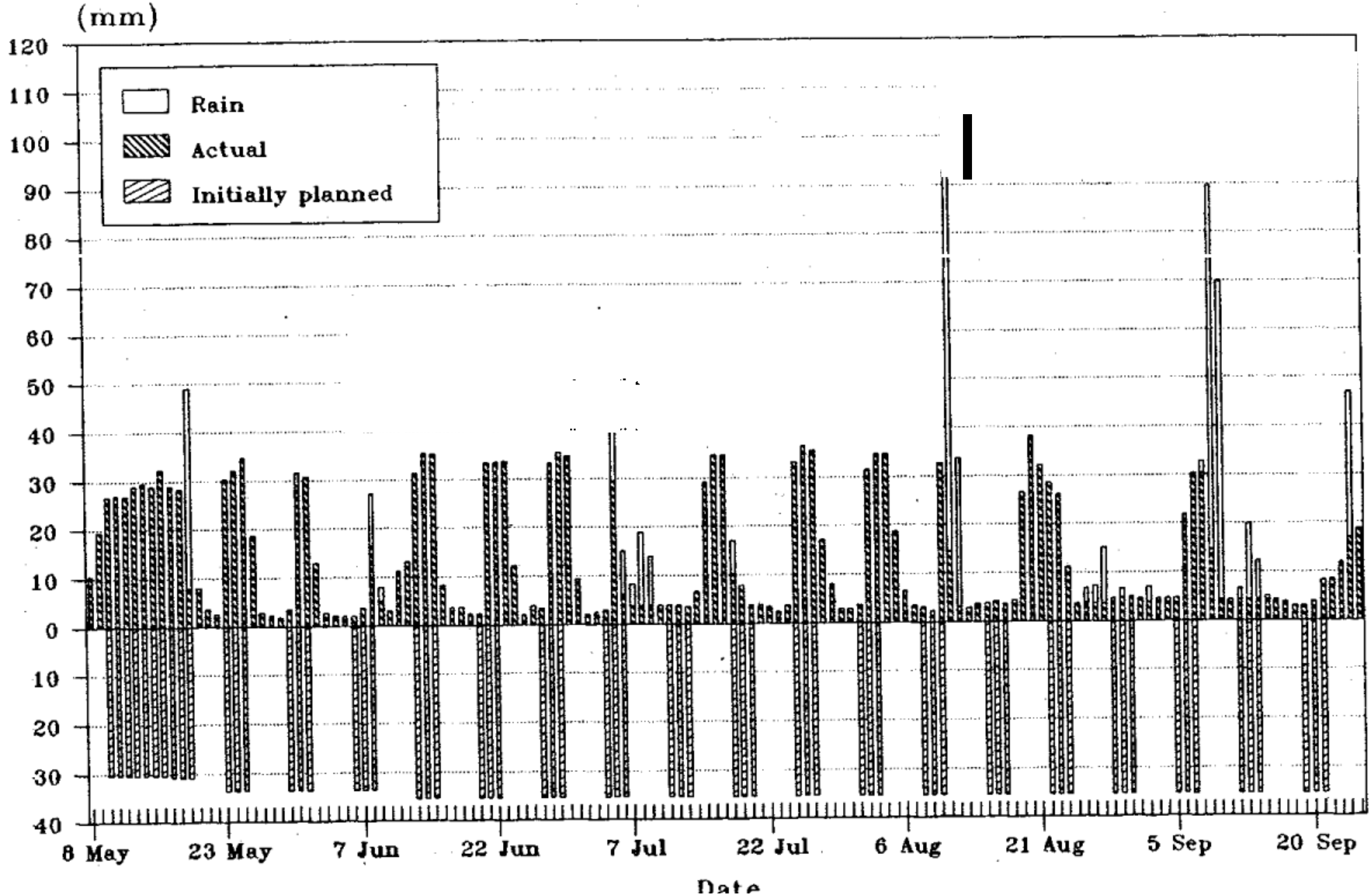


Figure IV.10 Water Level and Discharge at Gauge MS1

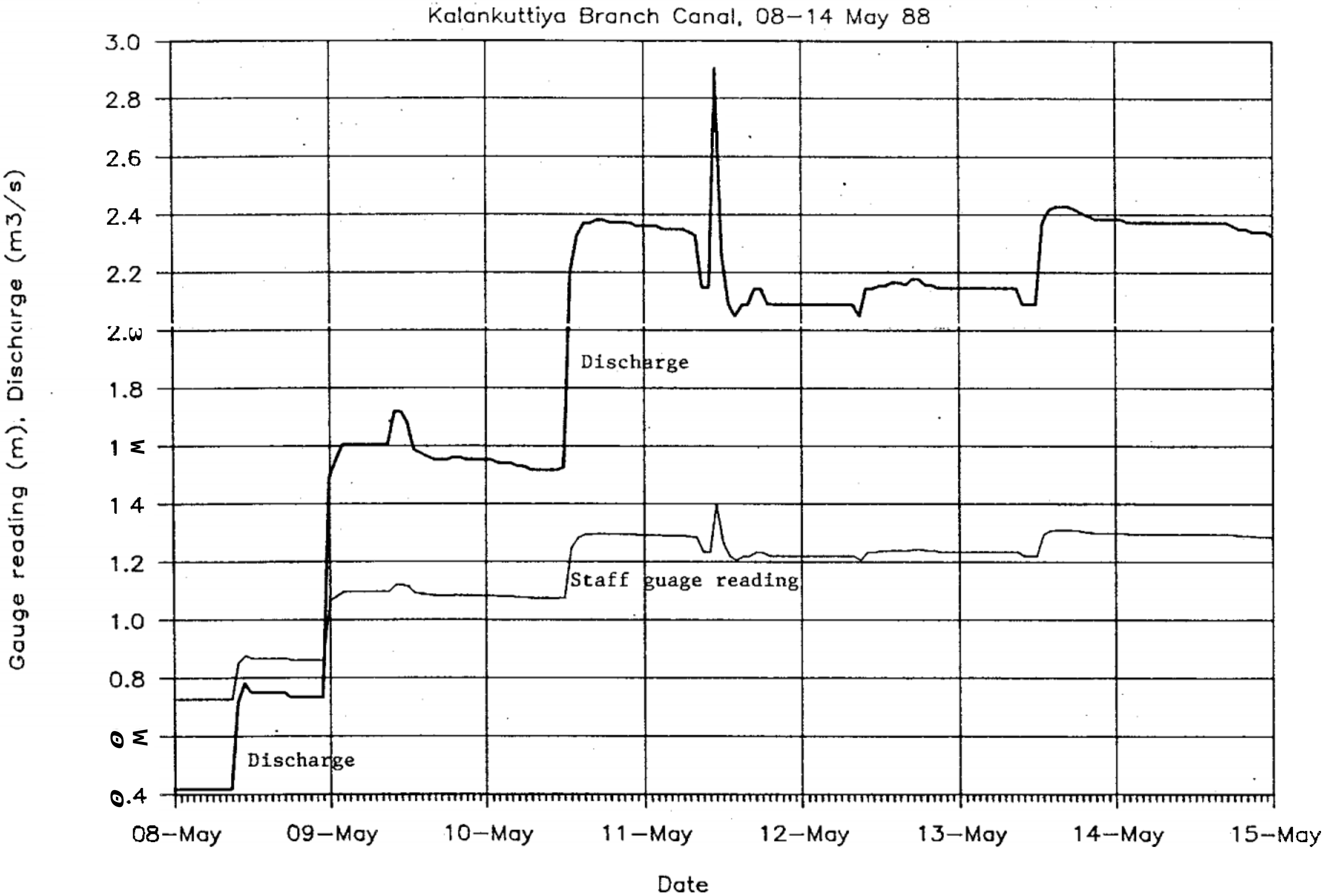


Figure 11 SDA main canal Headgate, data logging station

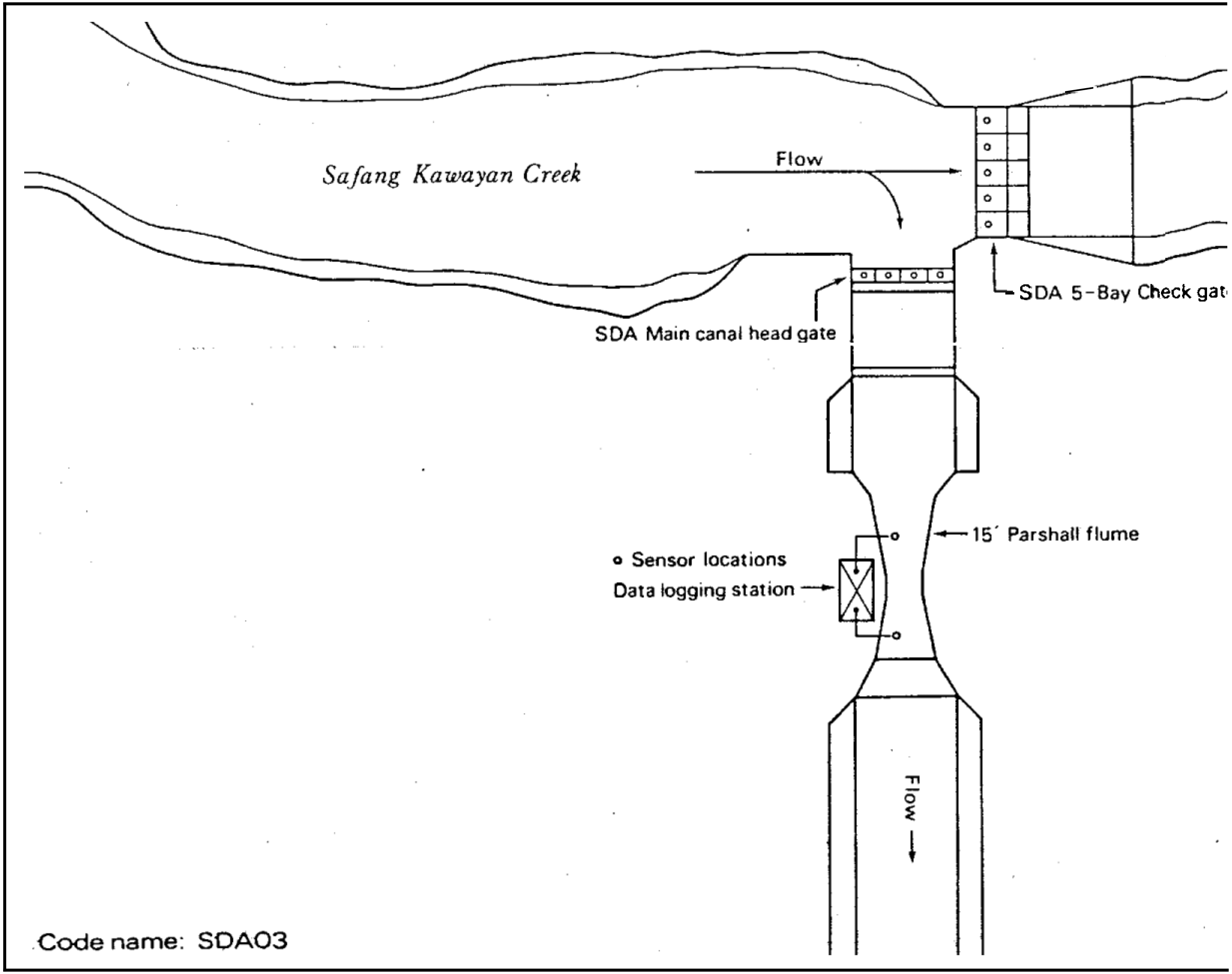


Figure IV.12 SDA, Discharges at Headgate

12 to 22 September 1988

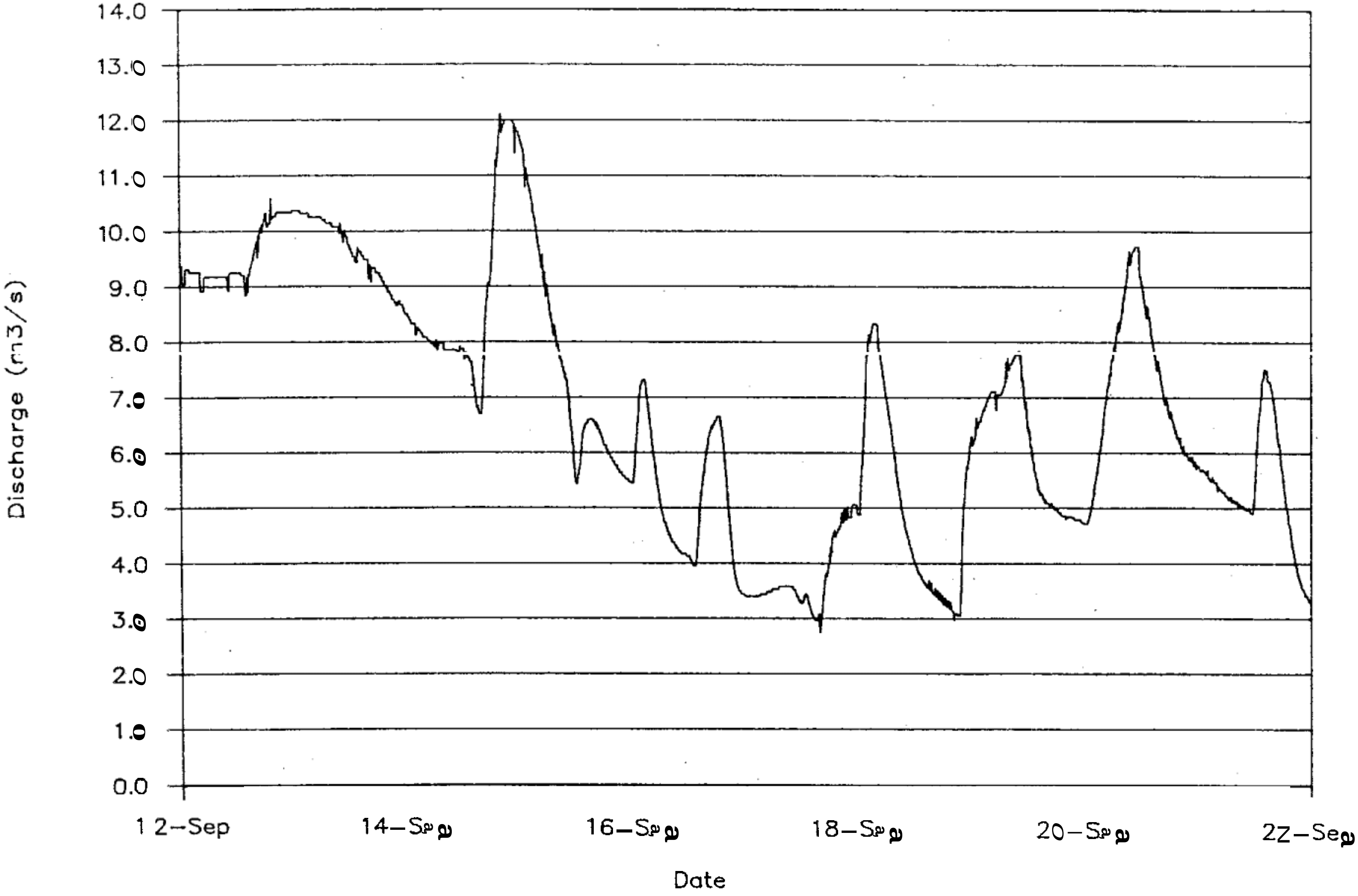


Figure IV 13

SDA Headgate

Calibration of 15 ft Parshall flume

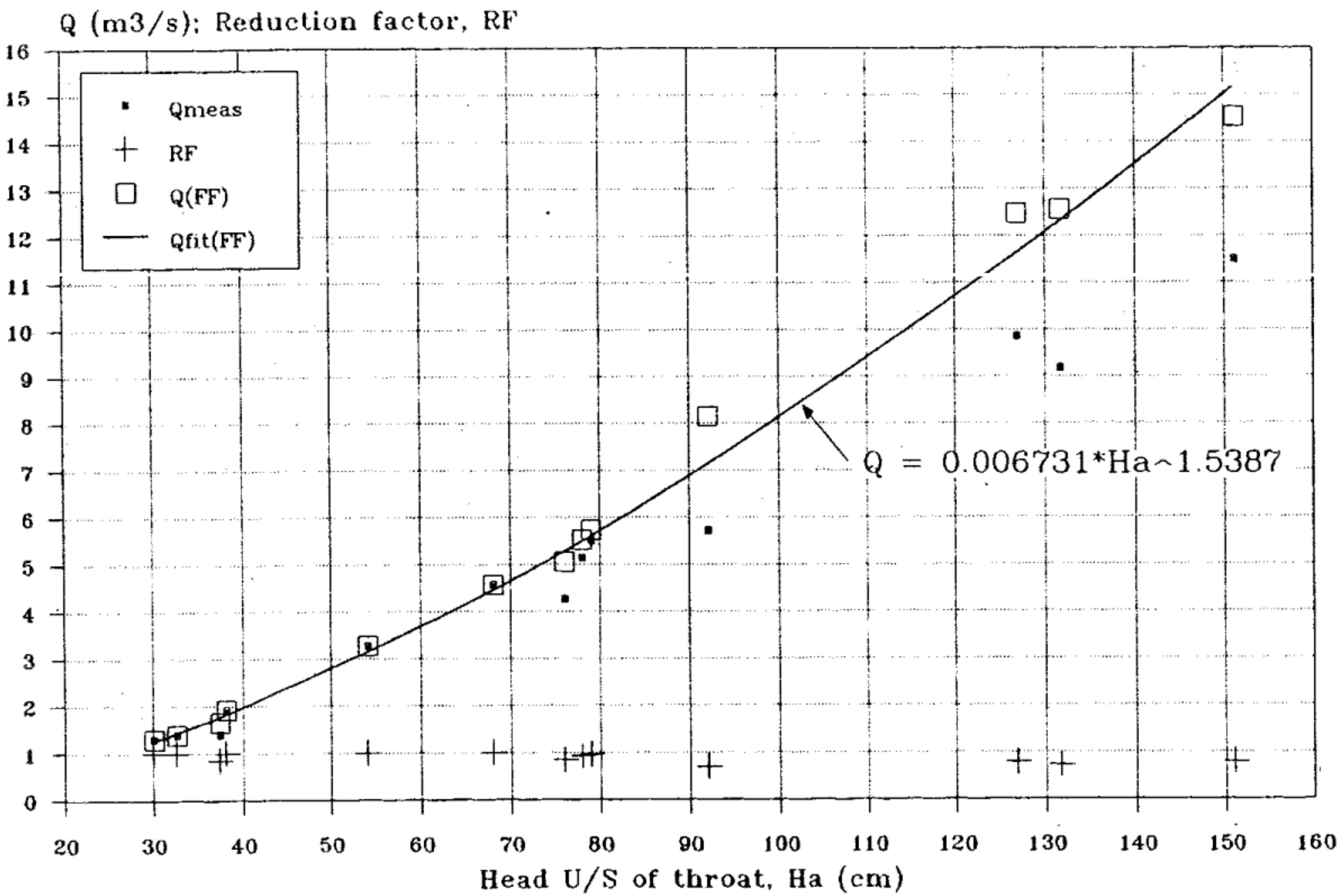


Figure IV.14 SDA Headgate (15 ft Parshall flume)
Comparison of discharge assessed using
NIA table(QNIA) with IIMI gauging(Qmeas)

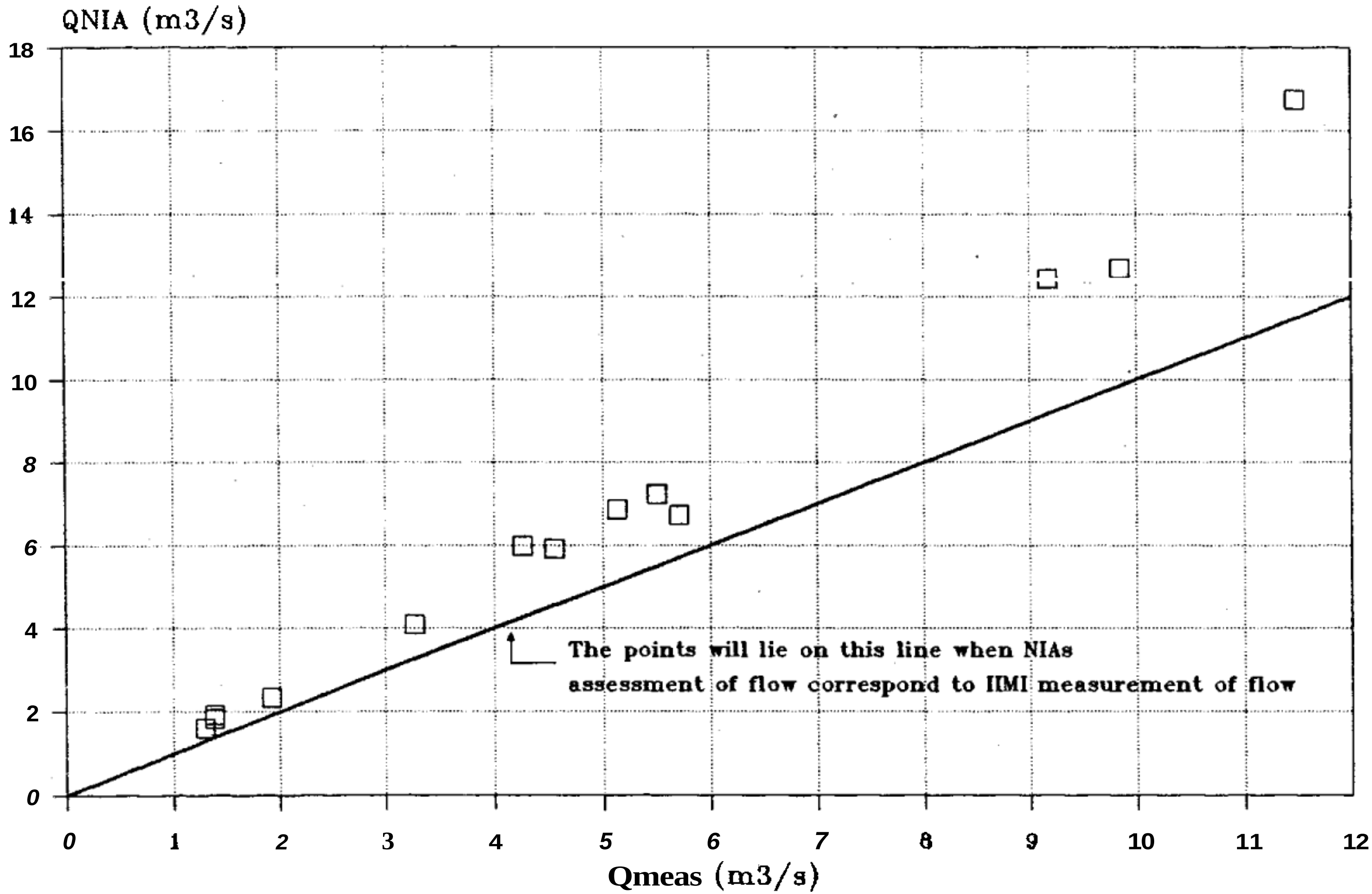


Figure IV.15 SDA Headgate Parshall flume : Effect of submergence

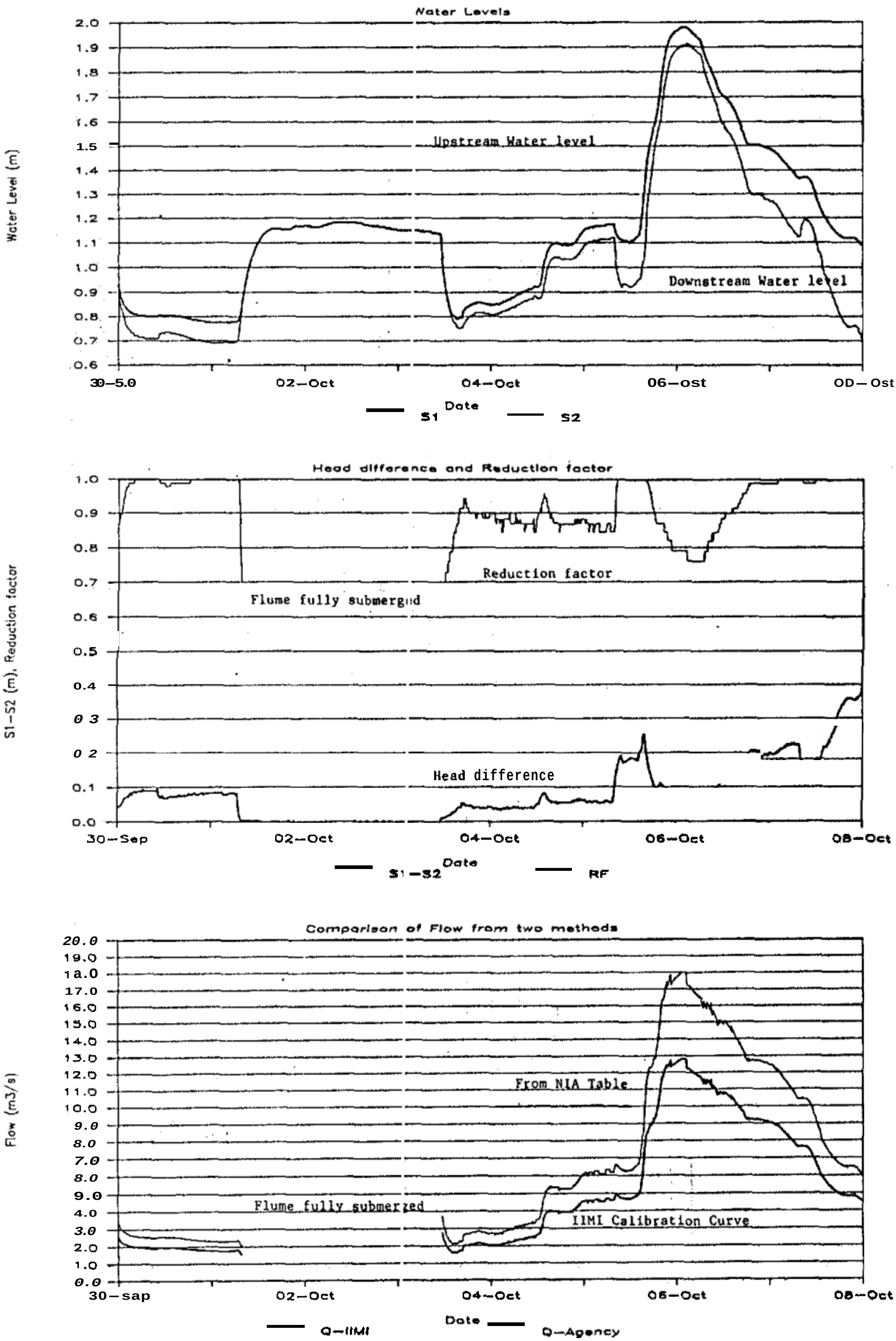


Figure IV.16 Sketch of data logging station, Pilot Area (DC1, Tract 2) Rajangana left bank main canal

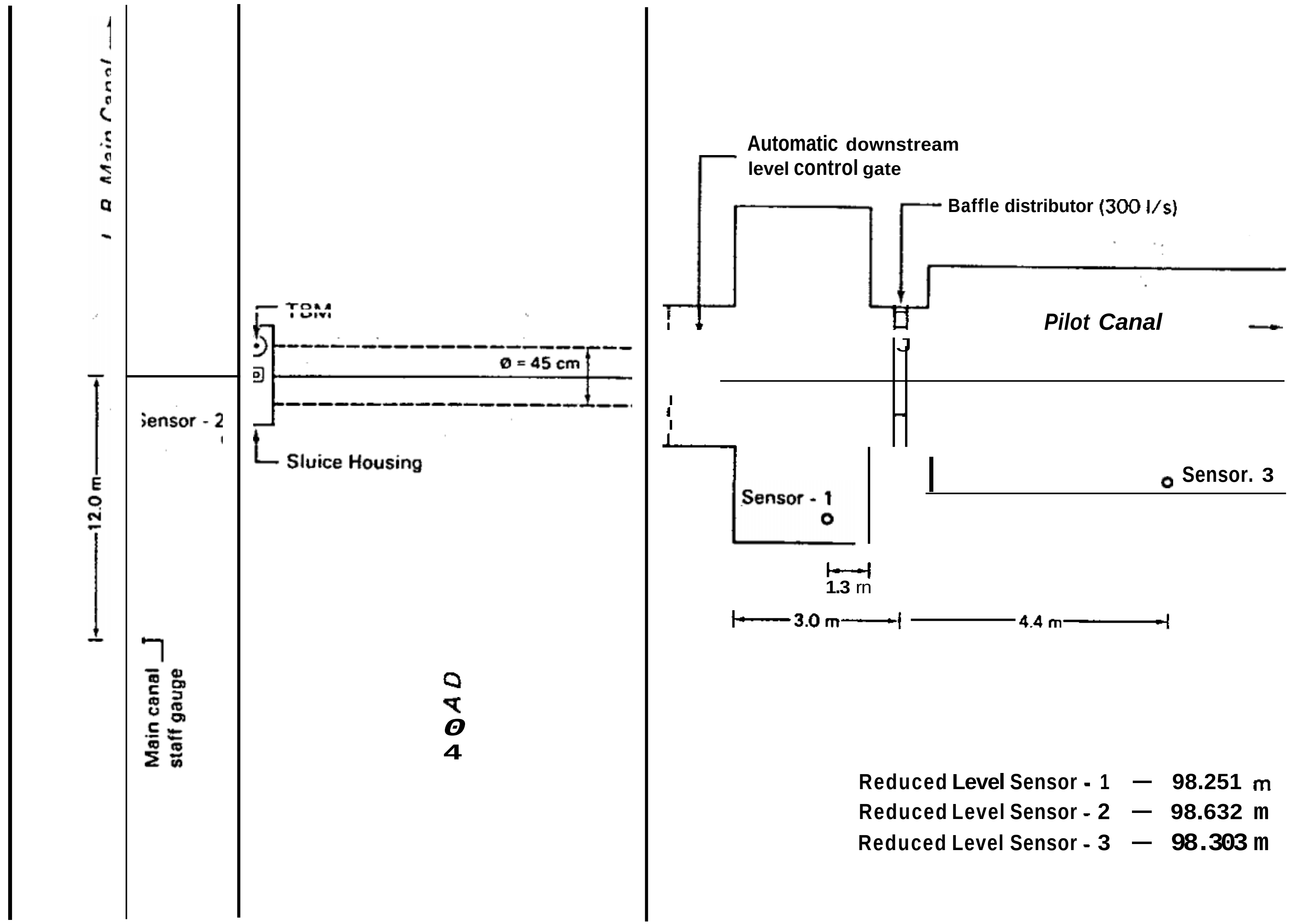


Figure IV.17 Sketch of data logging station, Control Area (DC2, Tract 2), Rajangana left bank main canal

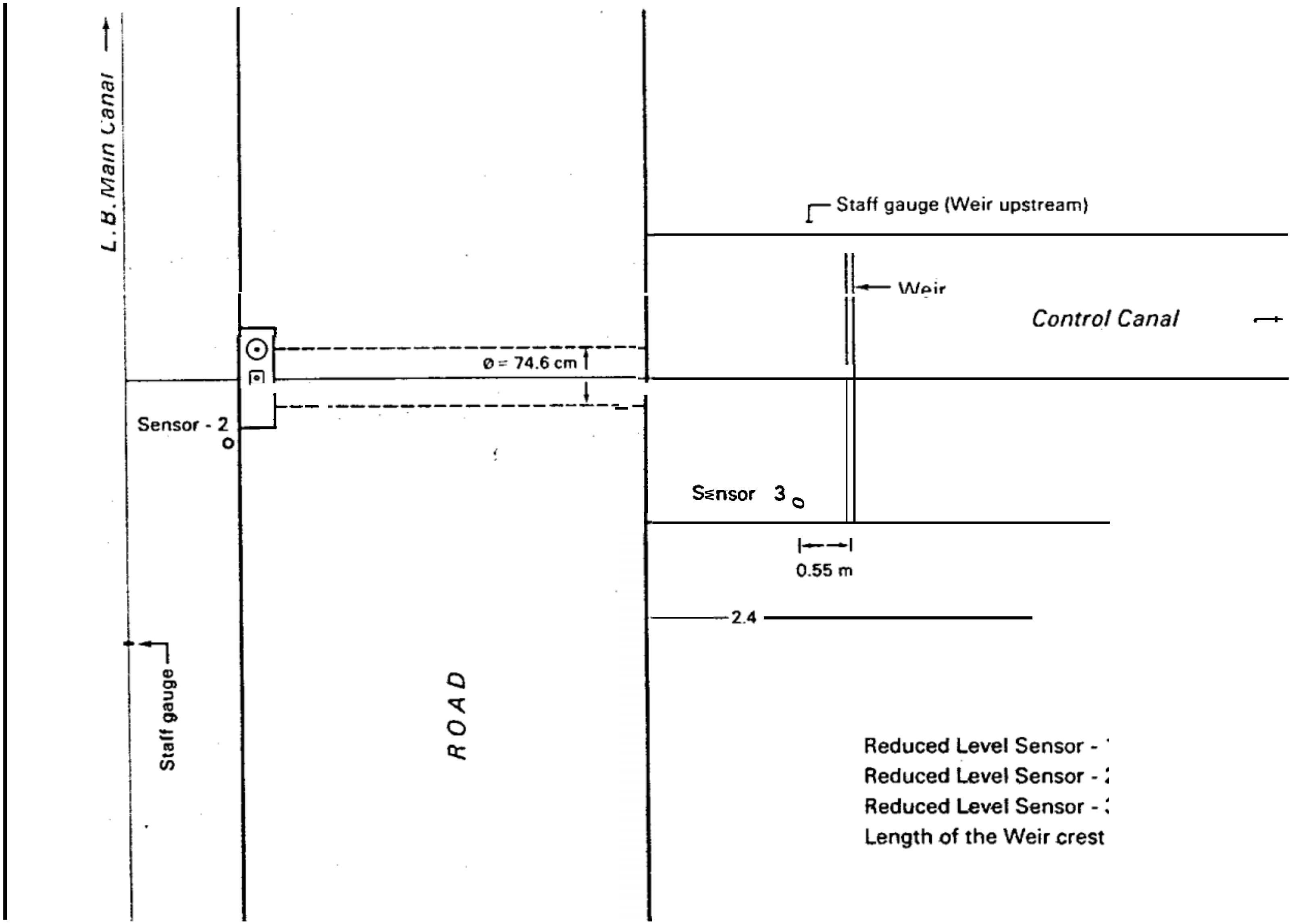
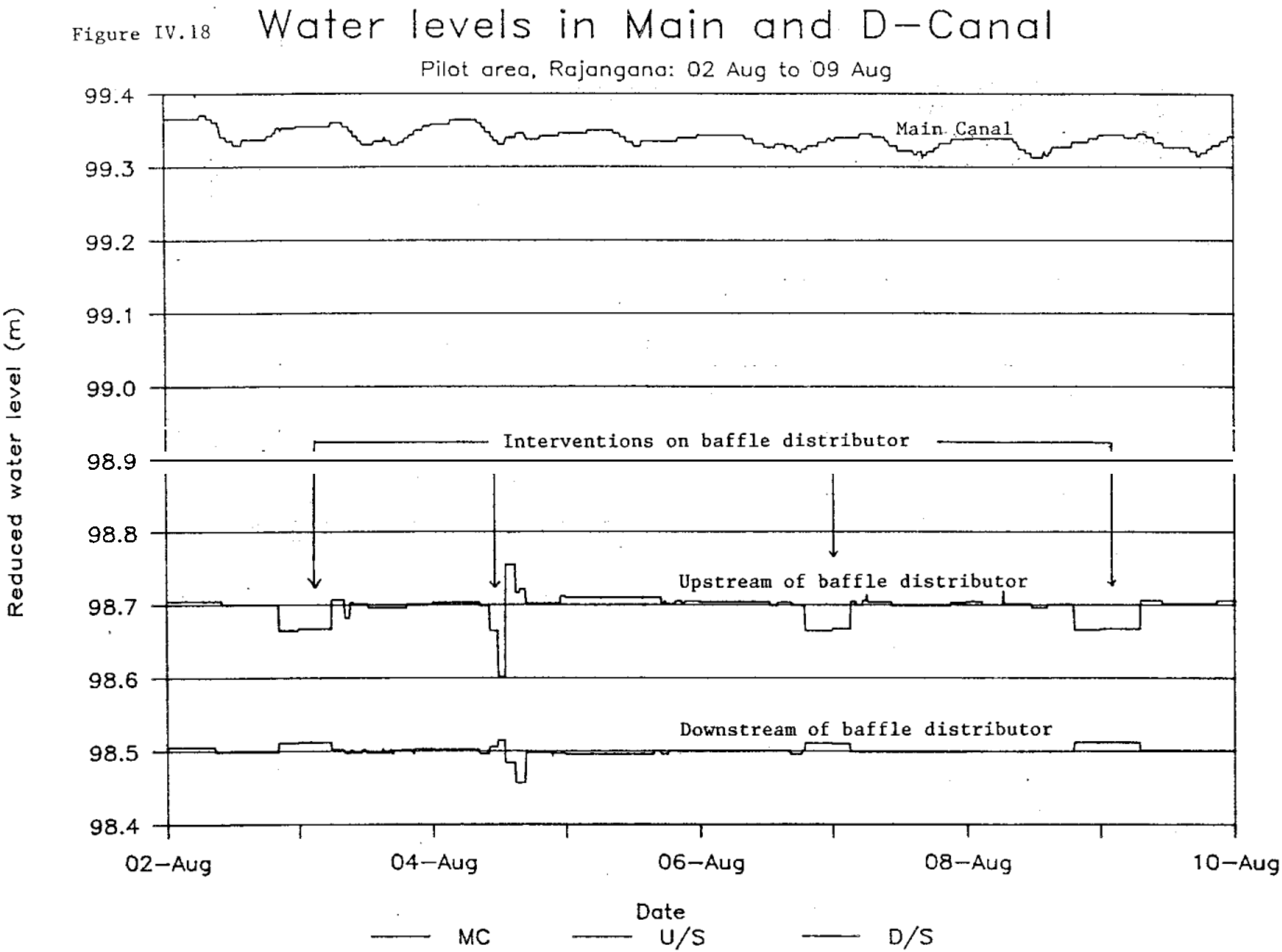


Figure IV.18



Water levels in Main and D-Canal
Pilot area, Rajangana: 02 Aug to 09 Aug
Reduced water level (m)
99.4
99.3
99.2
99.1
99.0
98.9
98.8
98.7
98.6
98.5
98.4
Main Canal
Interventions on baffle distributor
Upstream of baffle distributor
Downstream of baffle distributor
02-Aug
04-Aug
06-Aug
08-Aug
10-Aug
Date
MC
U/S
D/S

Figure IV.19 Sketch of SDA Lateral B measurement site

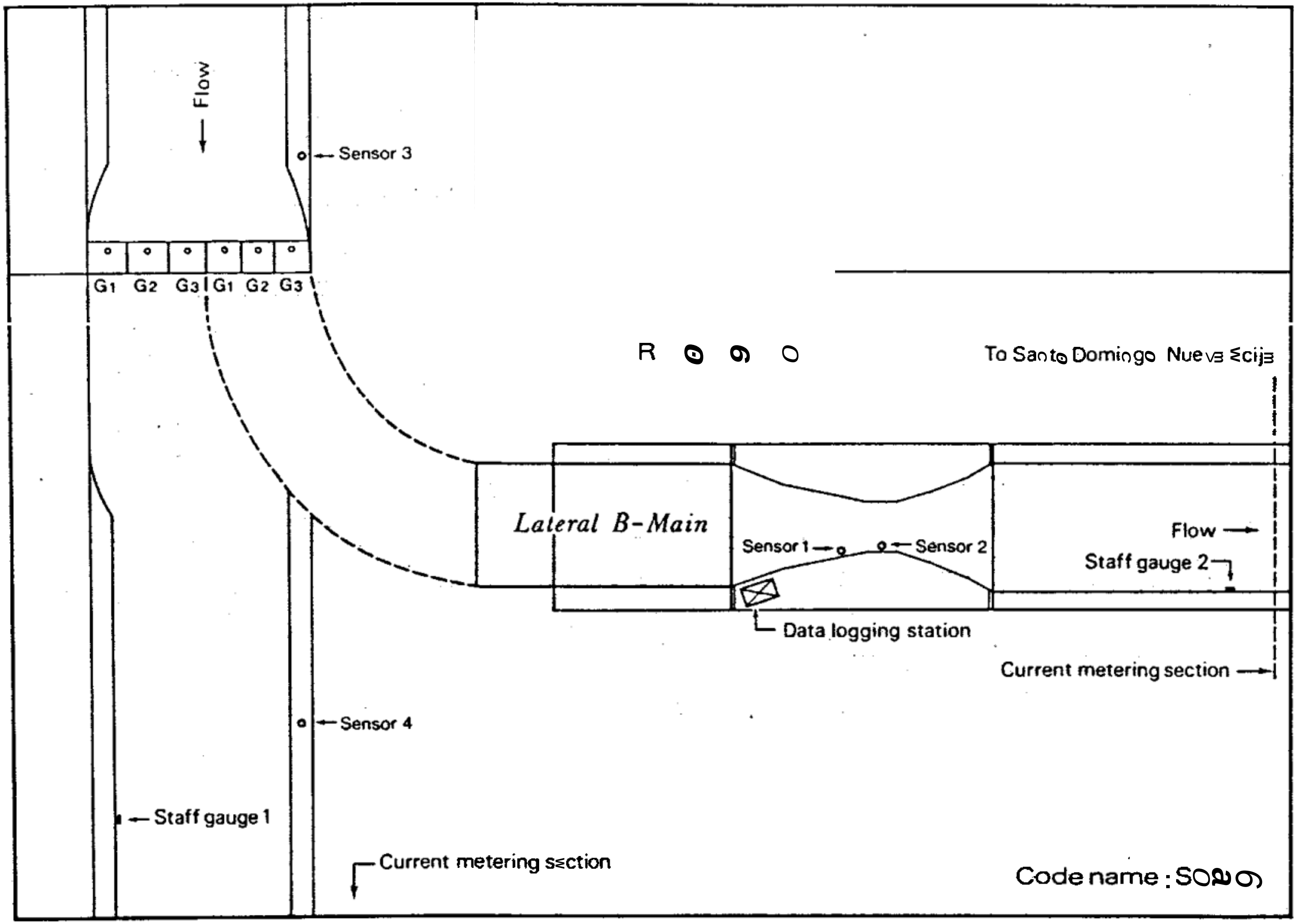


Figure IV.20 Sketch of SDA Lateral G measurement site

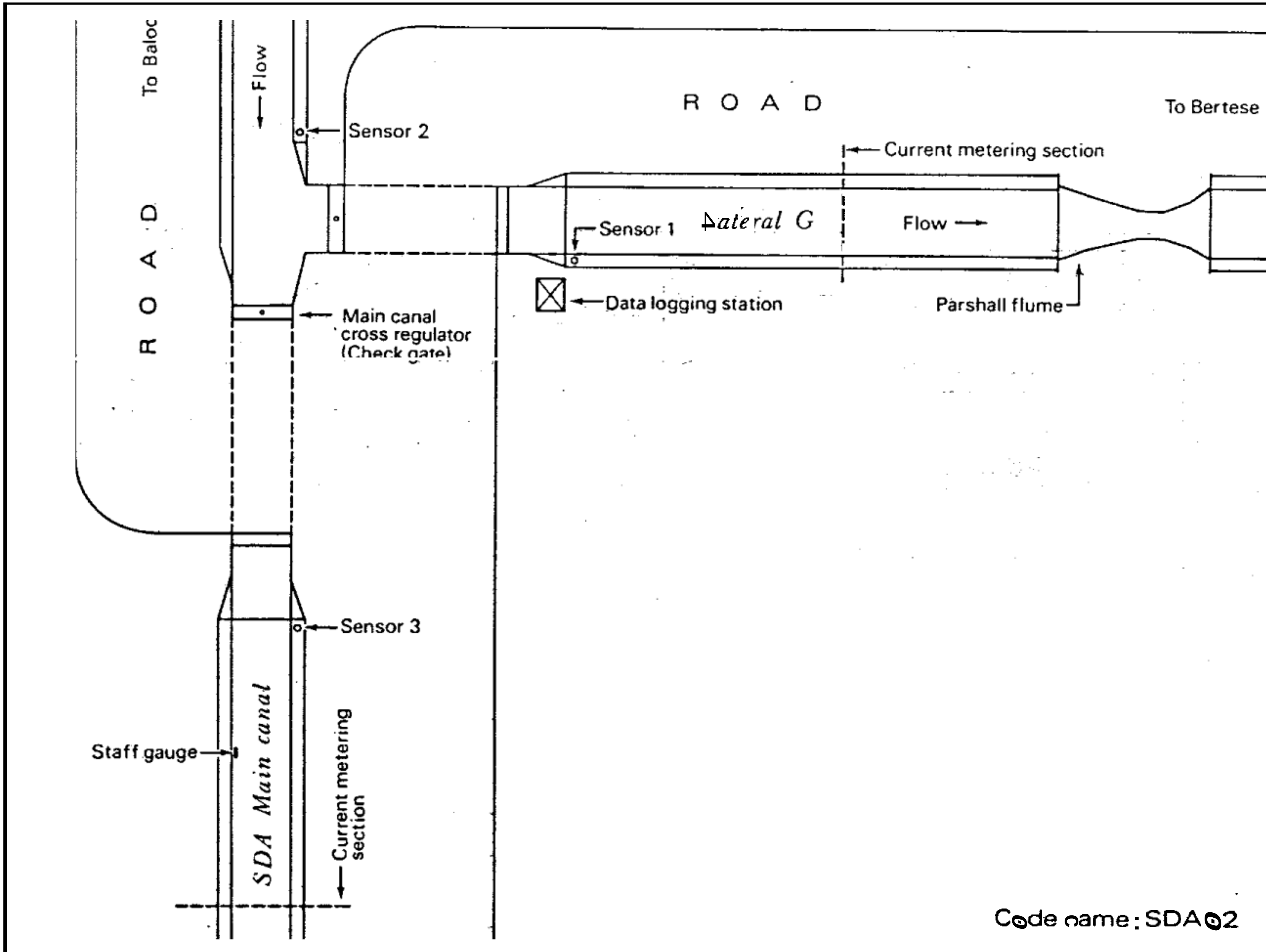


Figure IV.21 SDA, Daily discharges near Lateral B
21 July to 07 October 1988

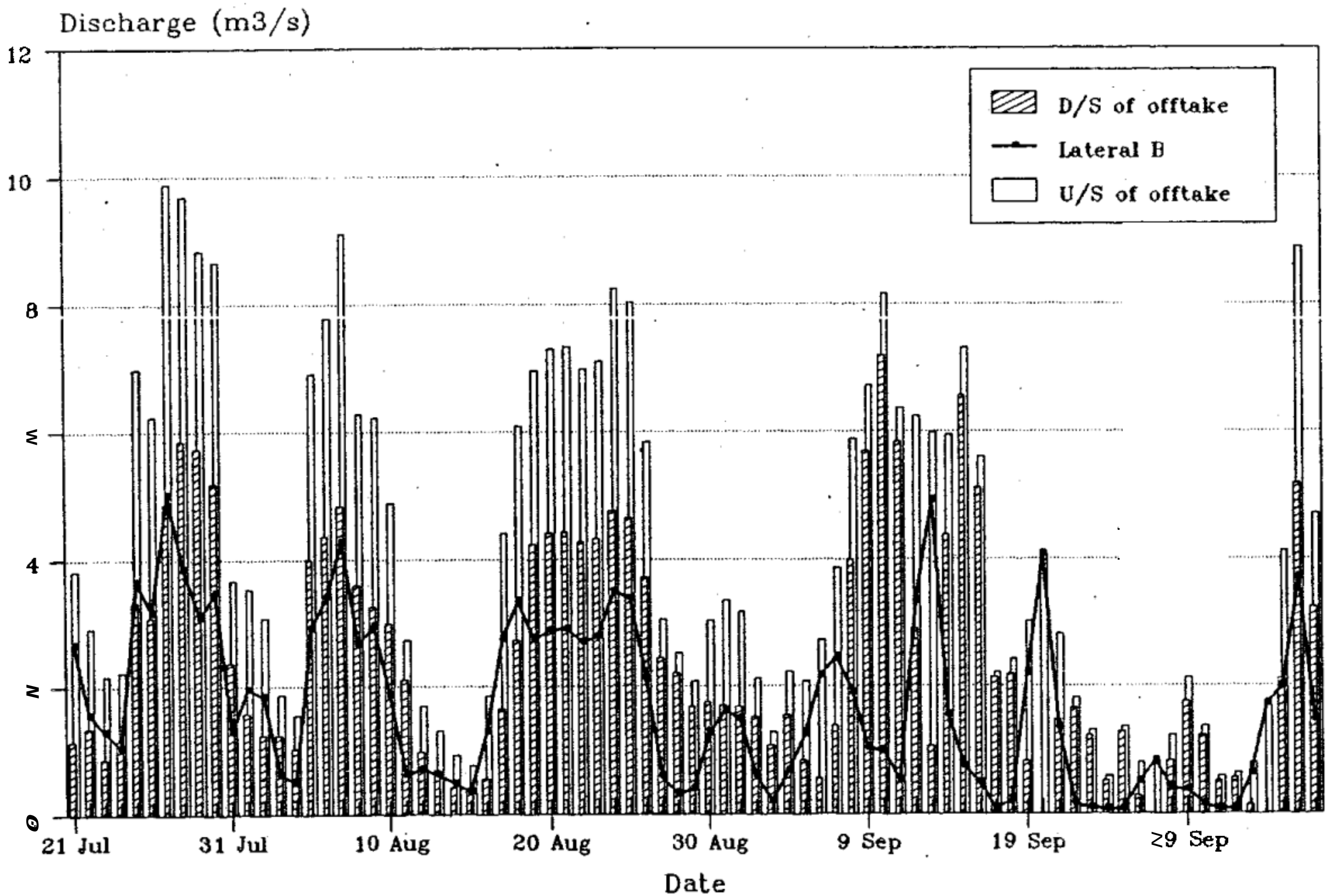


Figure IV.22 SDA, Daily discharges near Lateral G
24 August to 07 October 1988

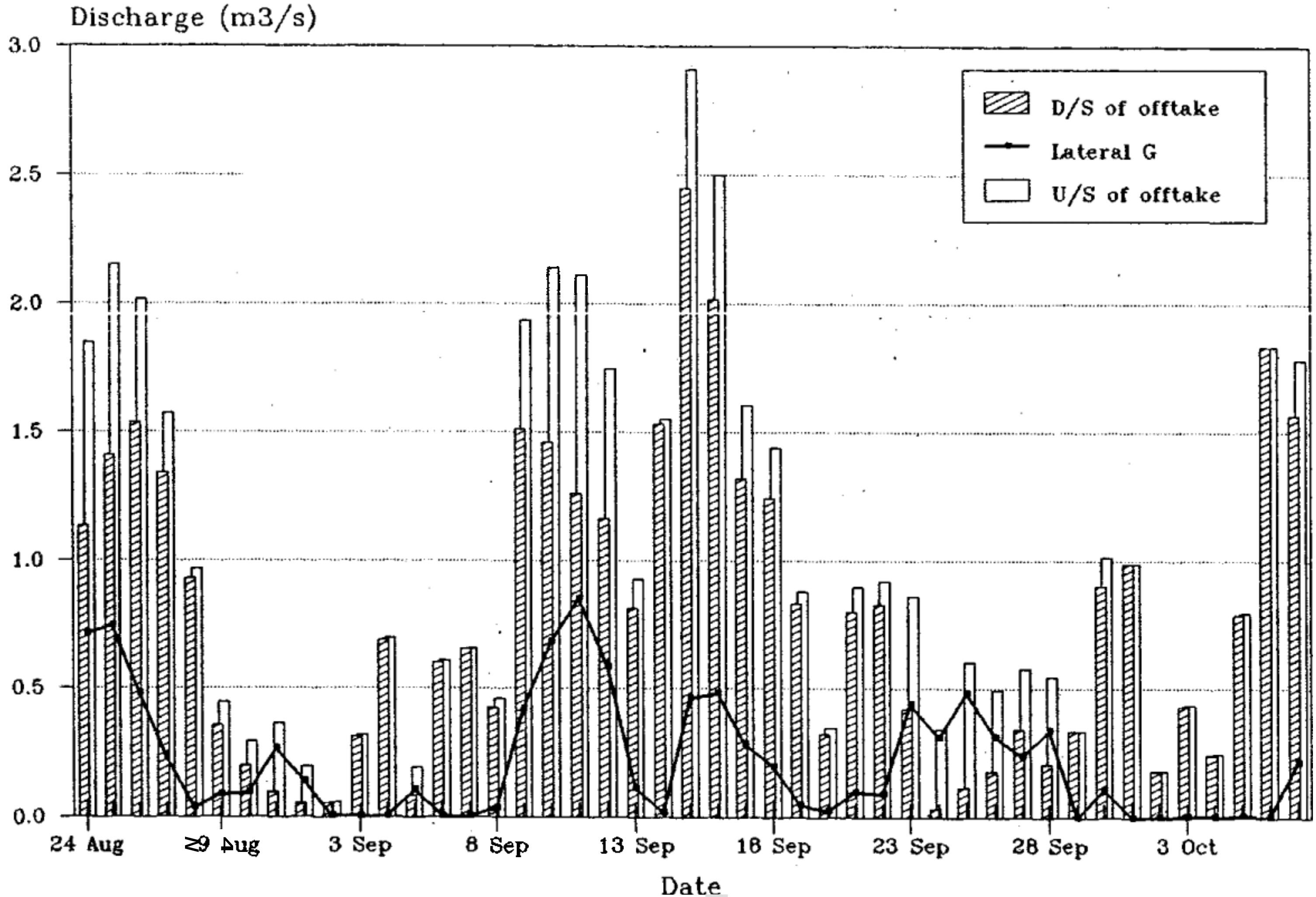


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Figure IV. 23 **SDA, Rotational irrigation schedule with effect from 12 September 1988**

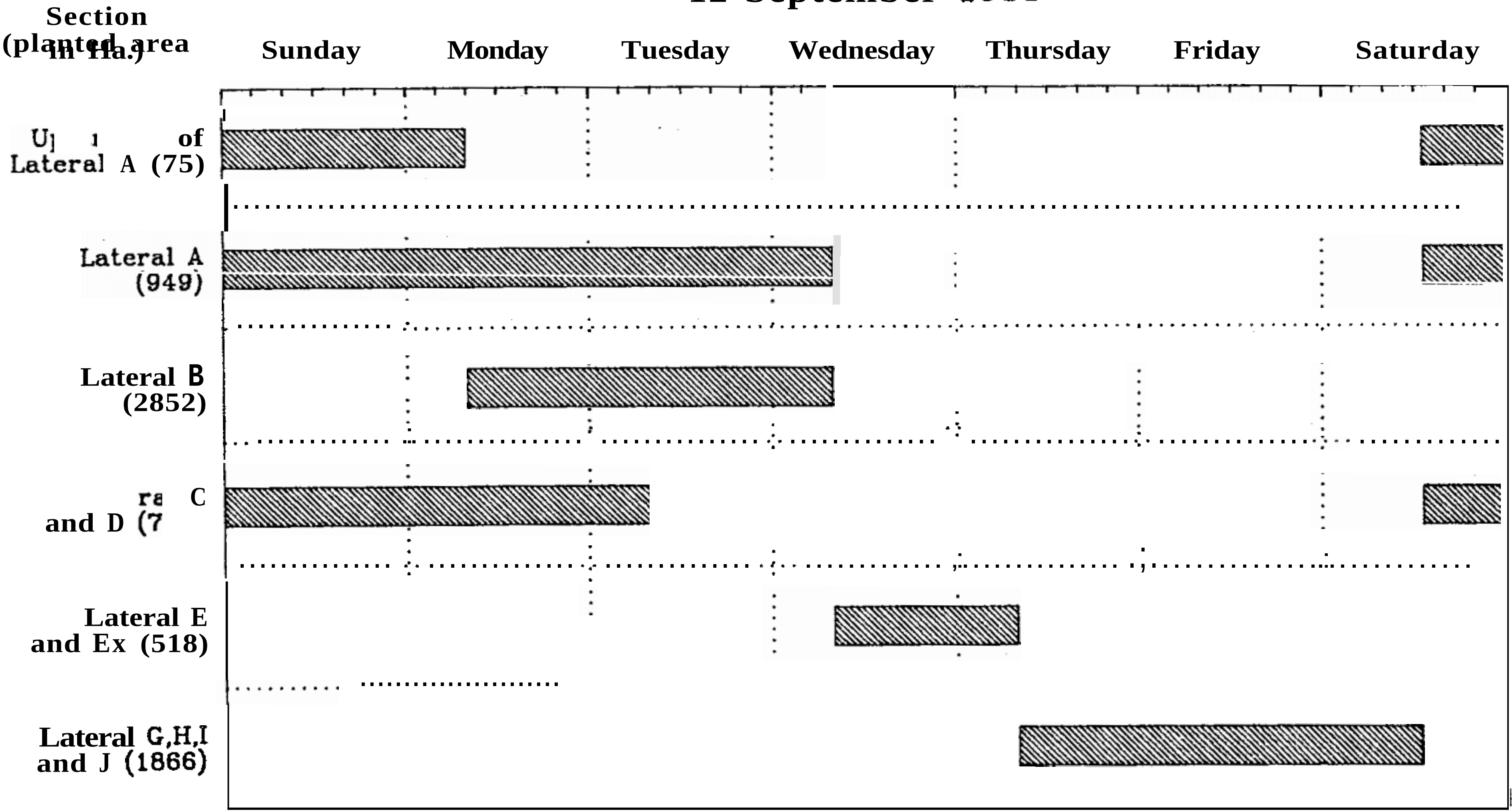
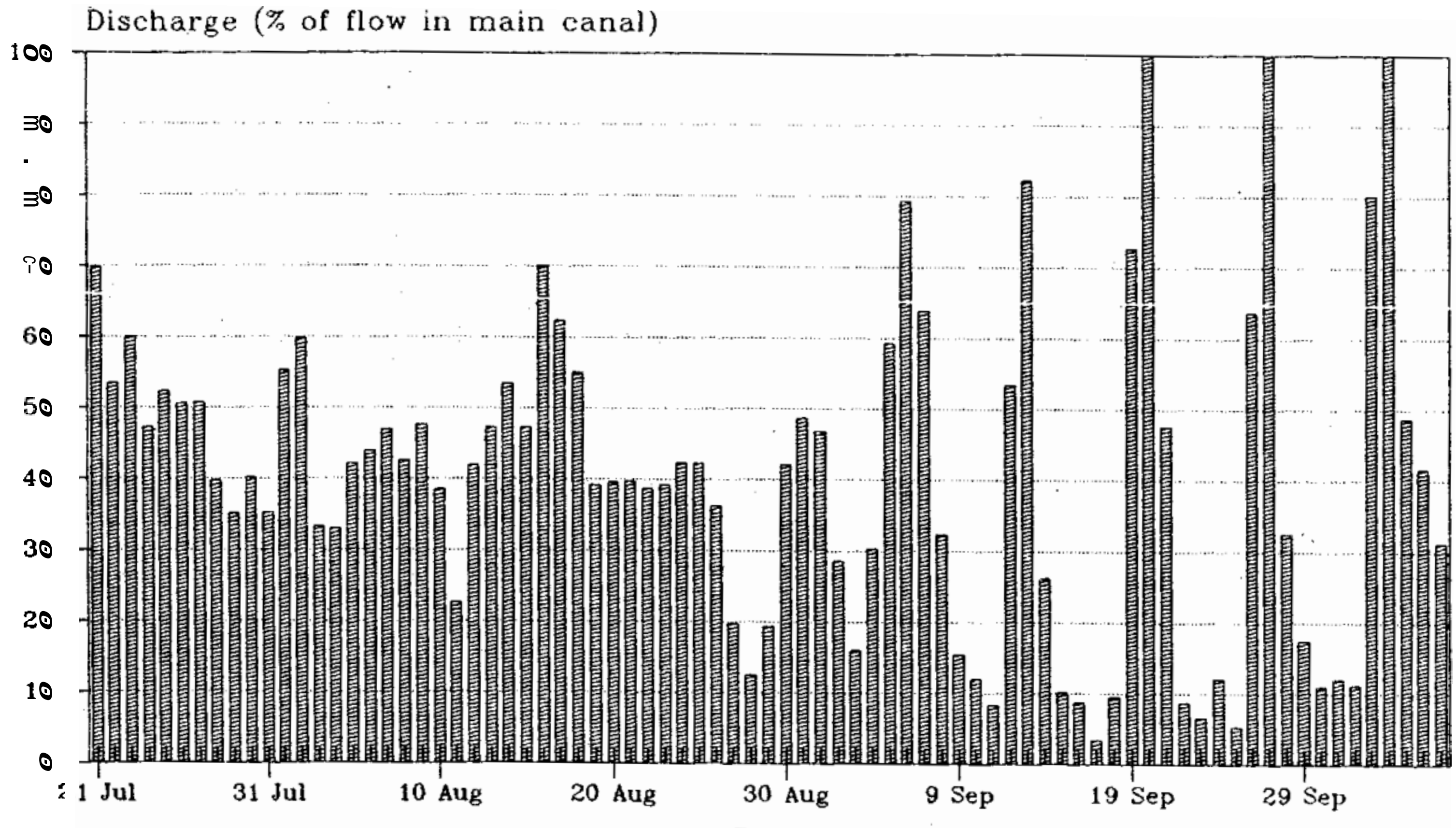
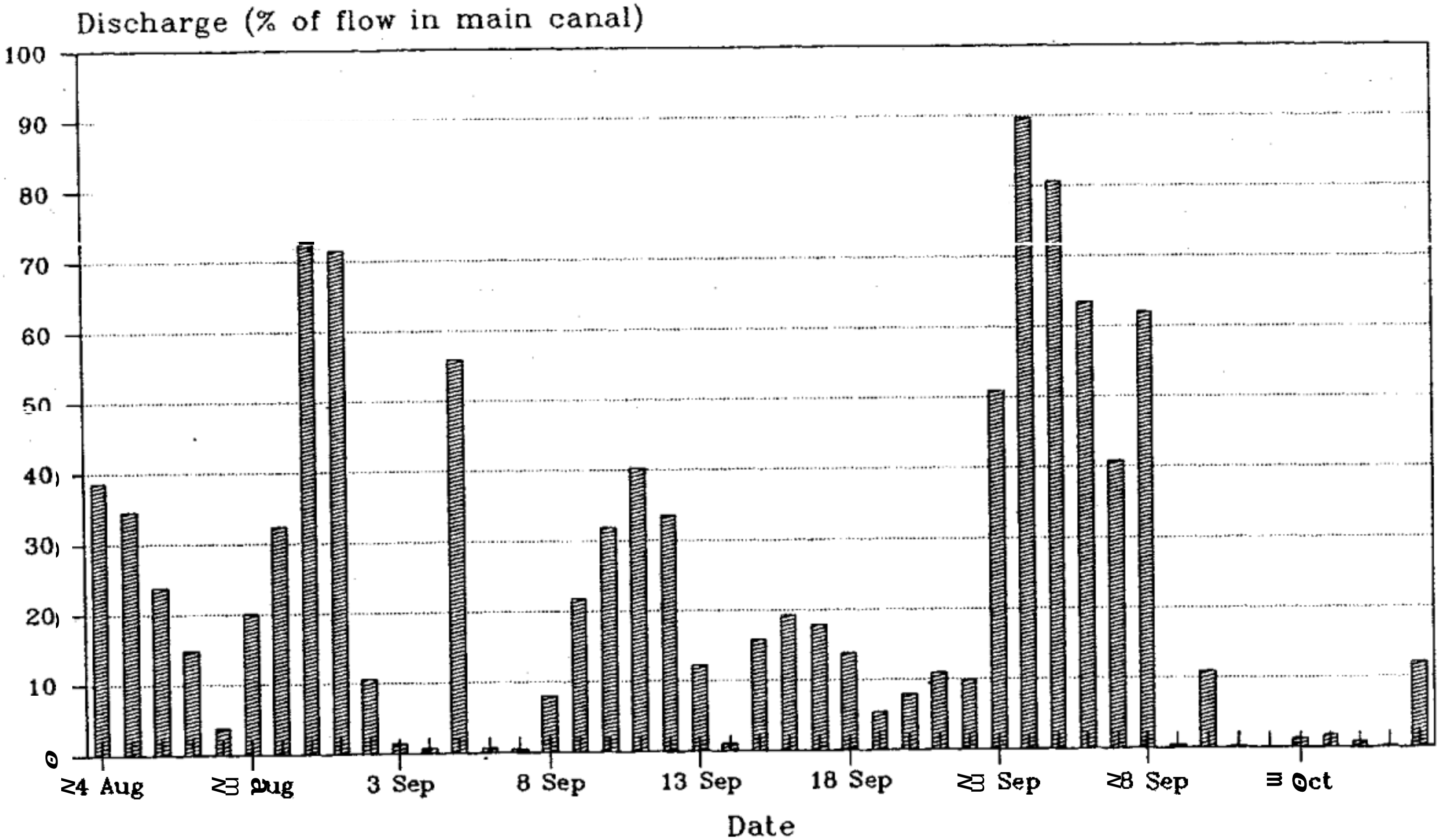


Figure IV.24 SDA, Daily discharge into Lateral B as a percentage of flow in main canal 21 July to 07 October 1988



Cultivated area served by flow in Lateral B is 40.6% of the area served flow upstream of Lateral B.

Figure IV 25 SDA, Daily discharge into Lateral G as a percentage of flow in main canal 24 August to 07 October 1988



Cultivated area served by flow in Lateral G is 38.7% of the area served by flow upstream of Lateral G.

Figure Iv.26

SDA (near Lateral B)

Interventions at gated regulator and impact on flow sharing, 24-31 July 1988

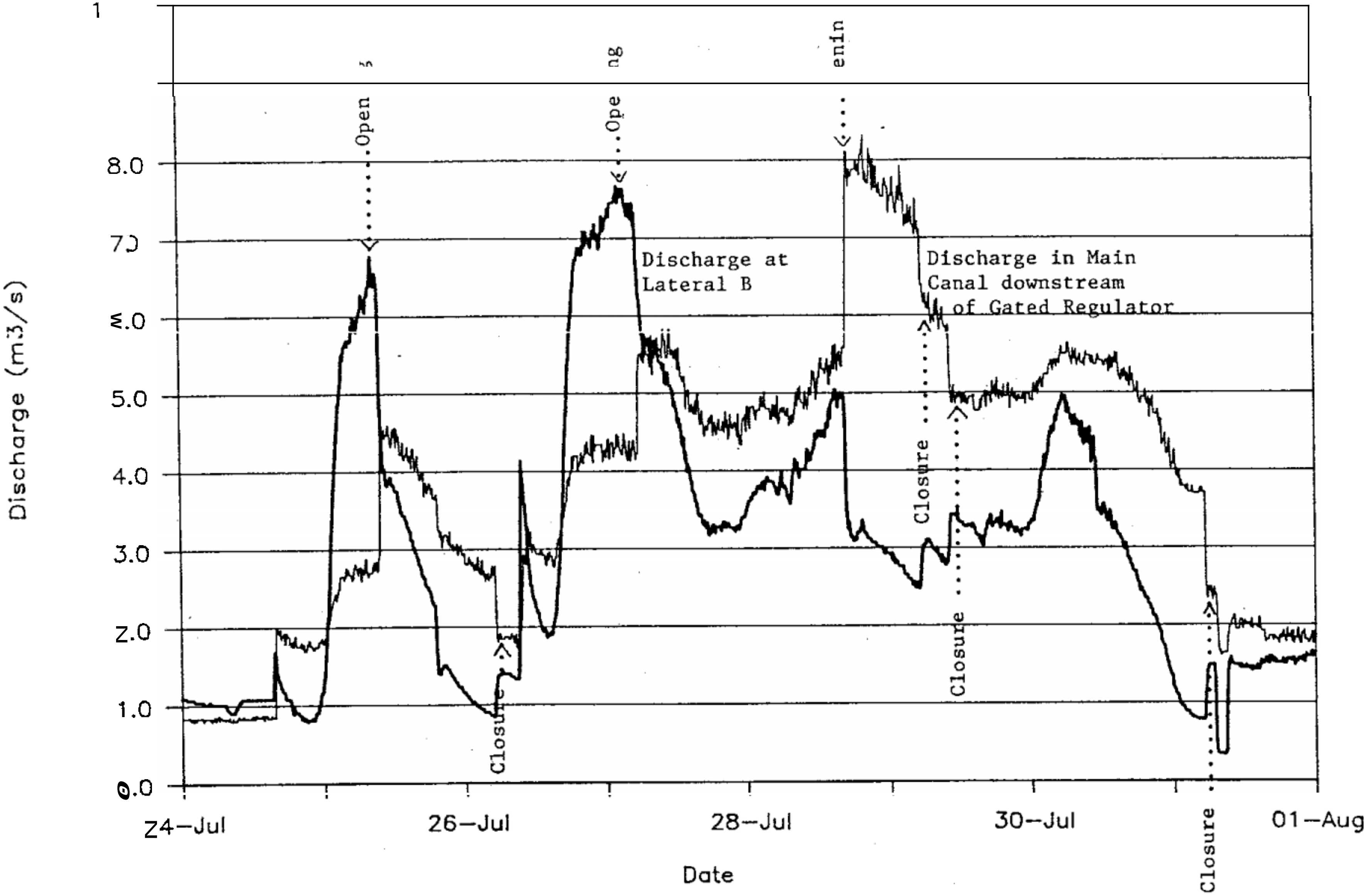


Figure IV.27 SDA, Discharges into Lateral B as a percentage of flow in main canal

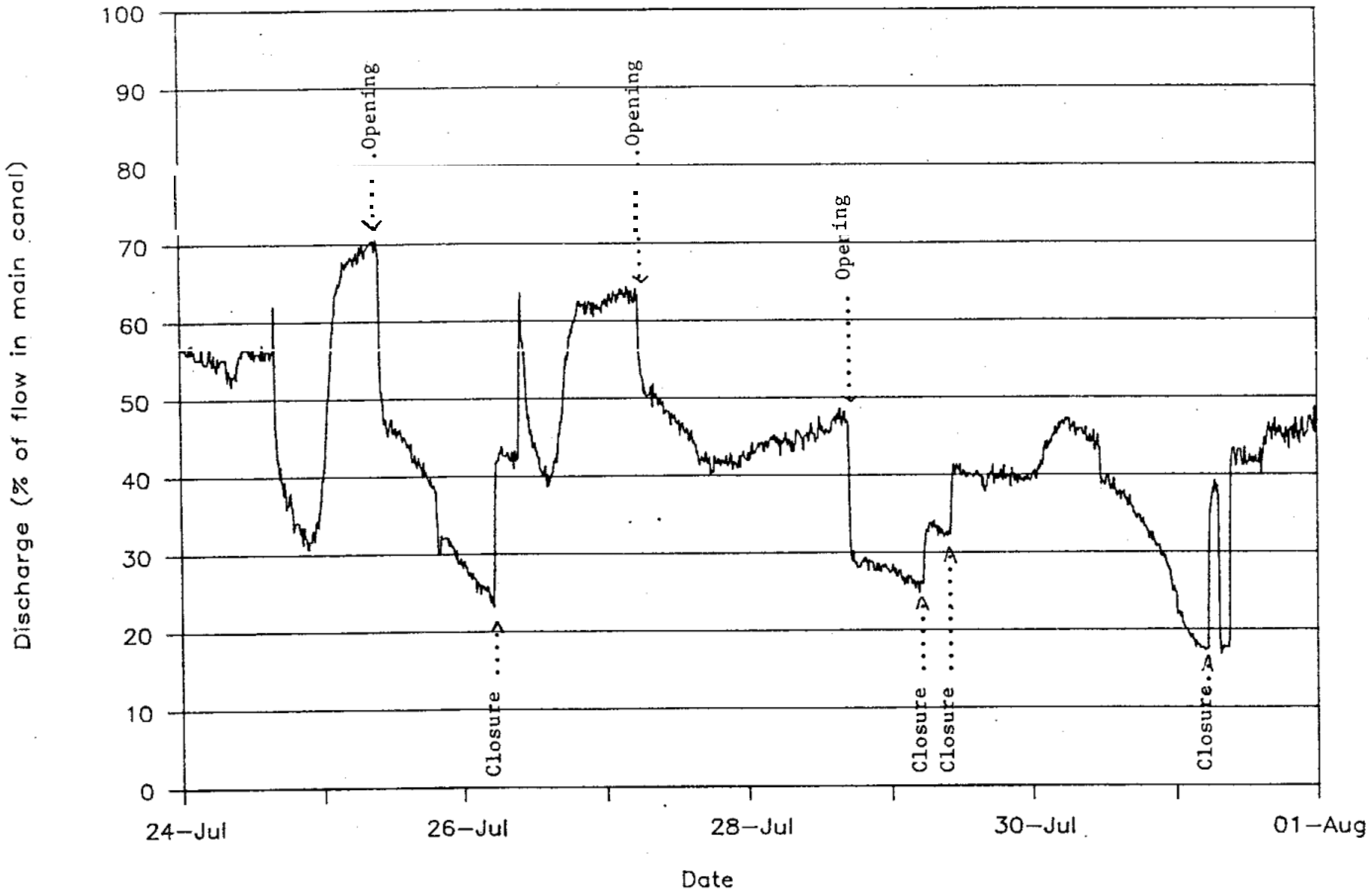


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Figure 1v.28 SDA Distribution of flow in Lateral B as a percentage of flow in main canal 24 to 31 July 1988

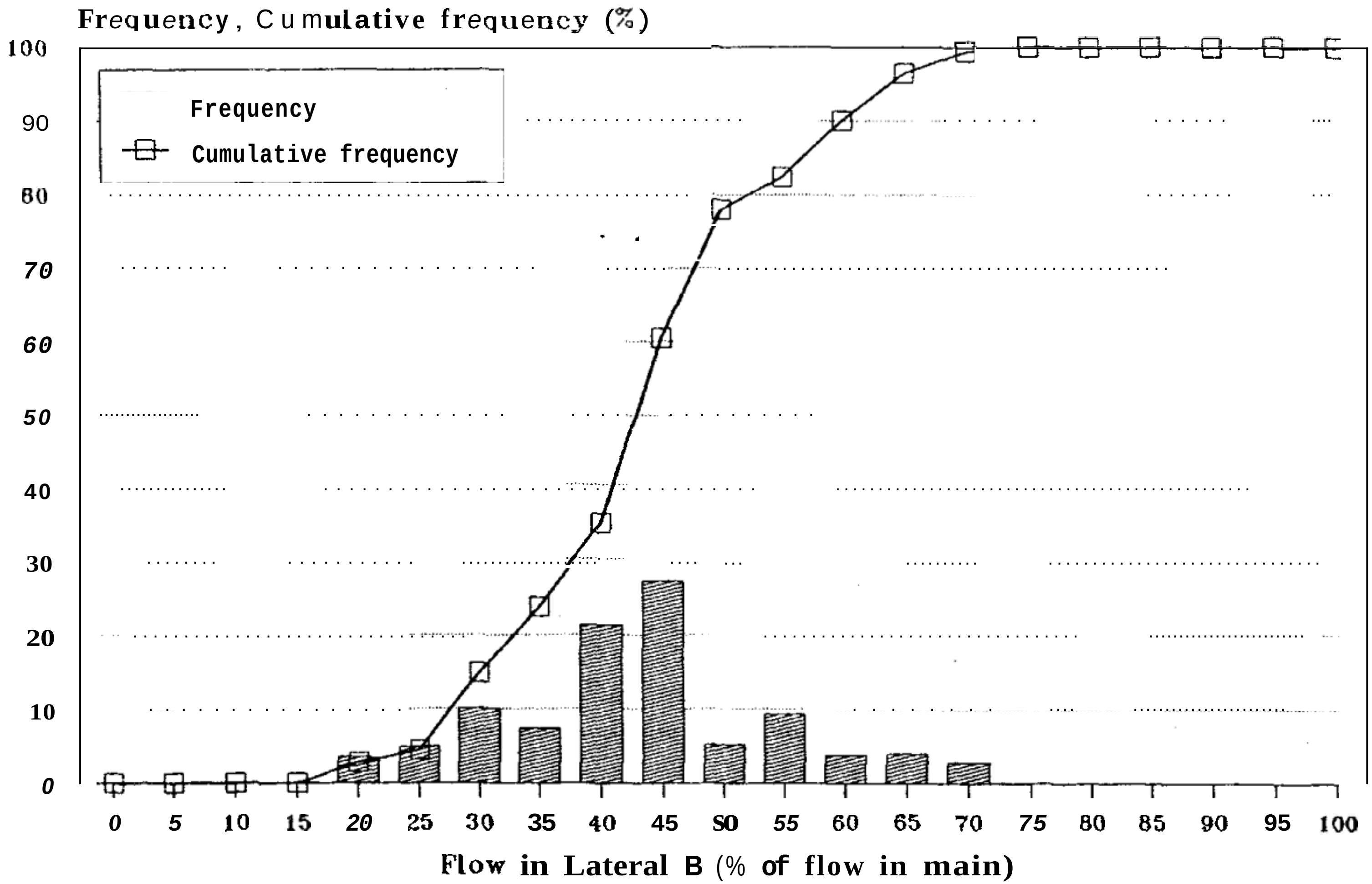


Figure IV.29 Kalankuetiya branch canal: Plan of data logging station near distributary canals 305D3 and 308D2

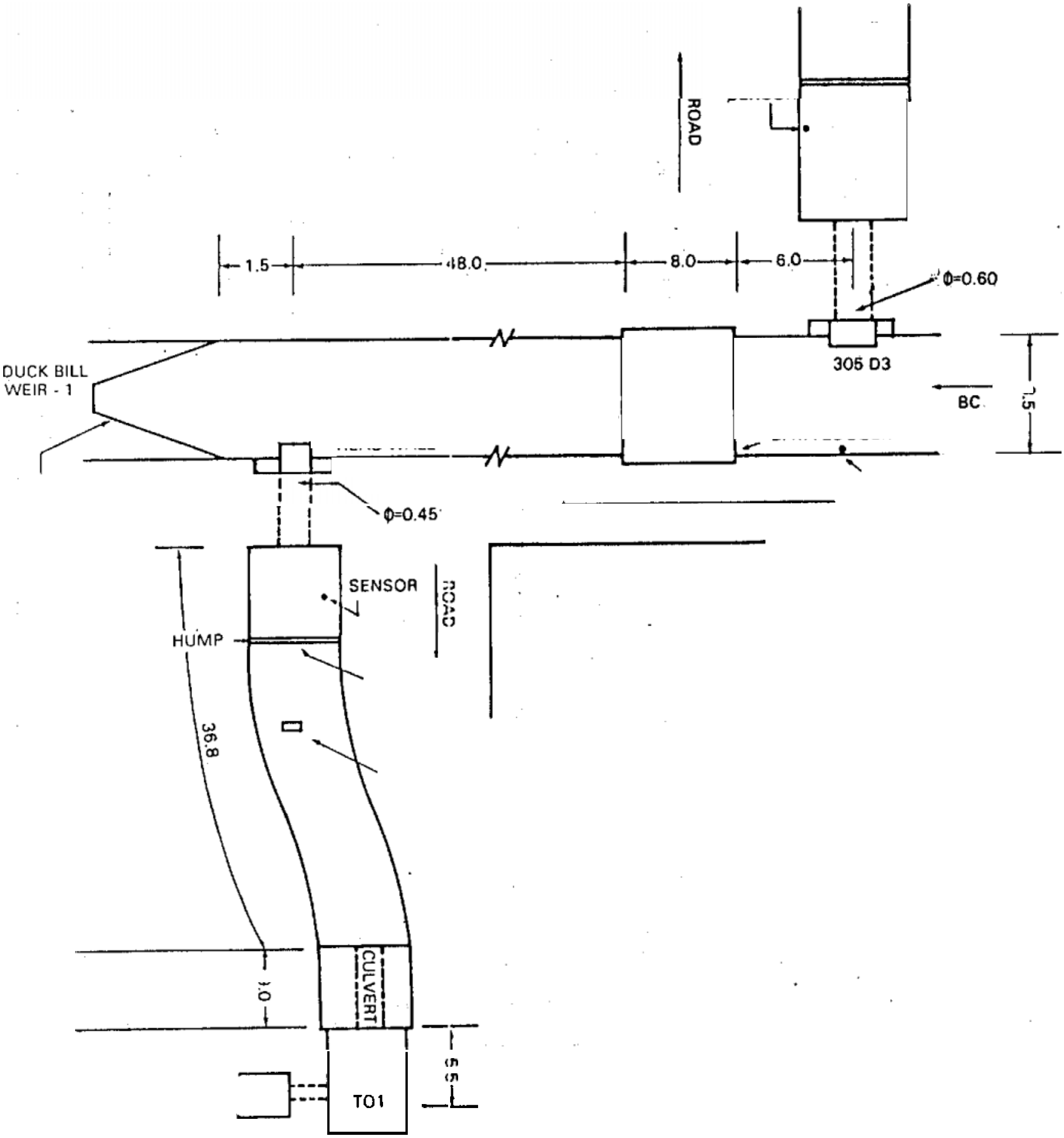
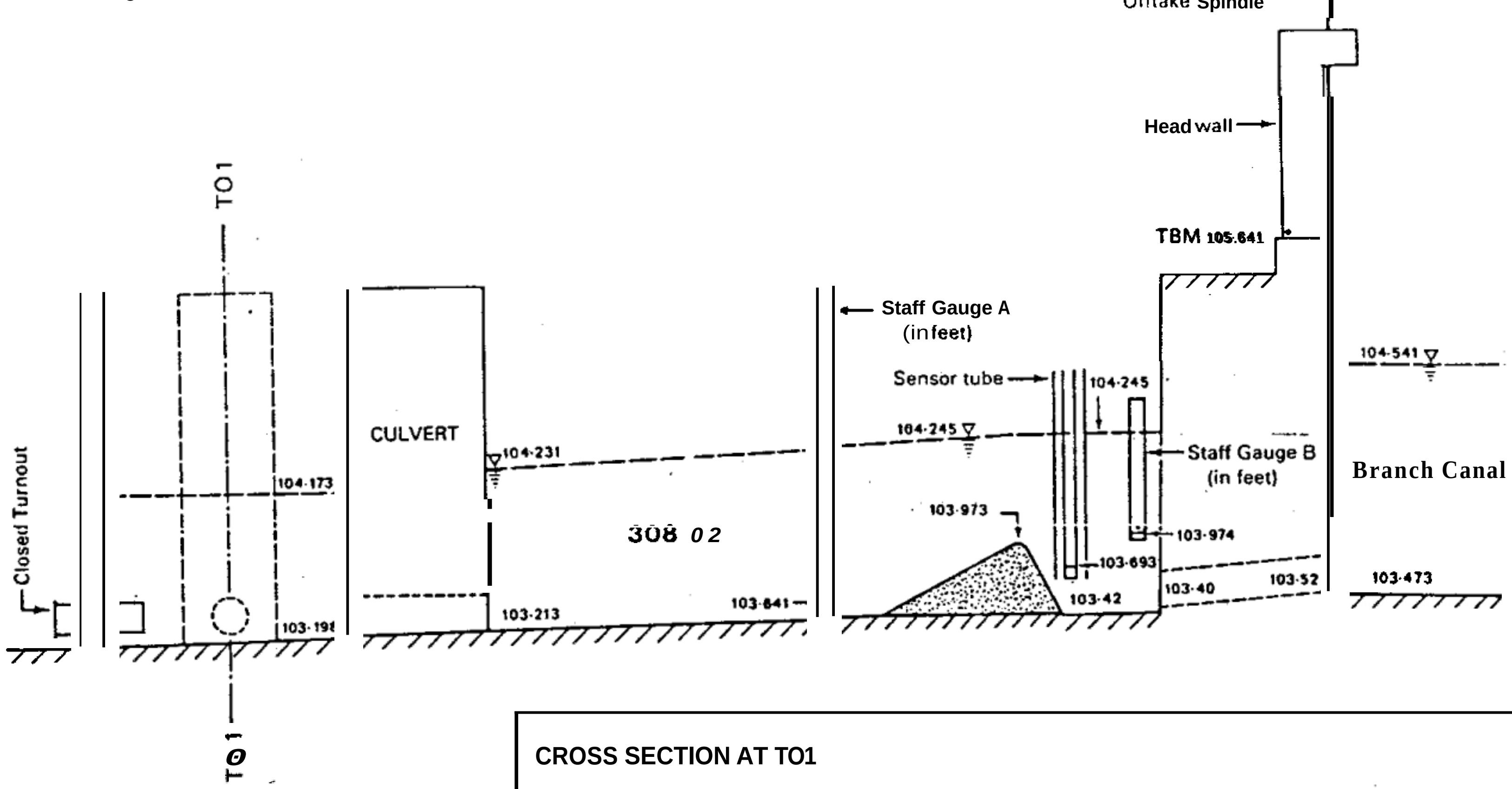
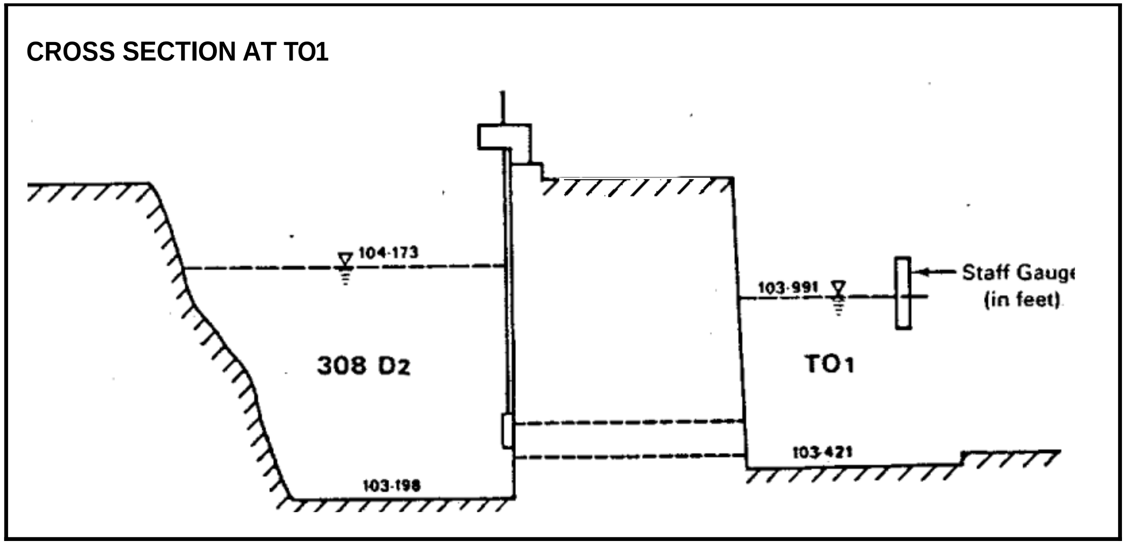


Figure IV.30 Longitudinal section near the head of distributary canal 308D2





Readings at 1600 hn. on 02nd August 1988

Offtake spindle height	=	33 cm
Sensor reading	=	552 mm
Staff gauge A	=	1.95 ft.
Staff gauge B	=	0.89 ft.

Figure IV.31 Cross sectional view of offtake of distributary canal 305D3

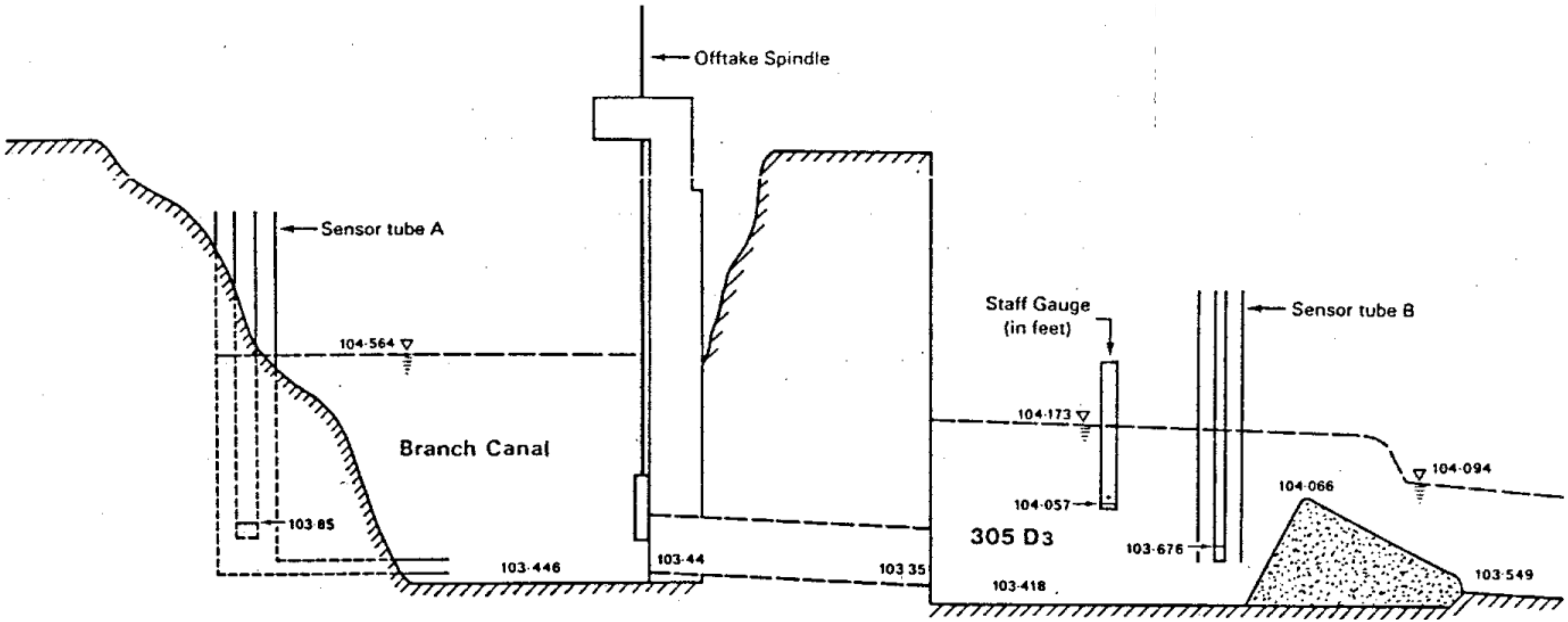


Figure IV.32 Kalankuttiya, Water level variations

near DB—Weir 1, 21 to 24 June 1988

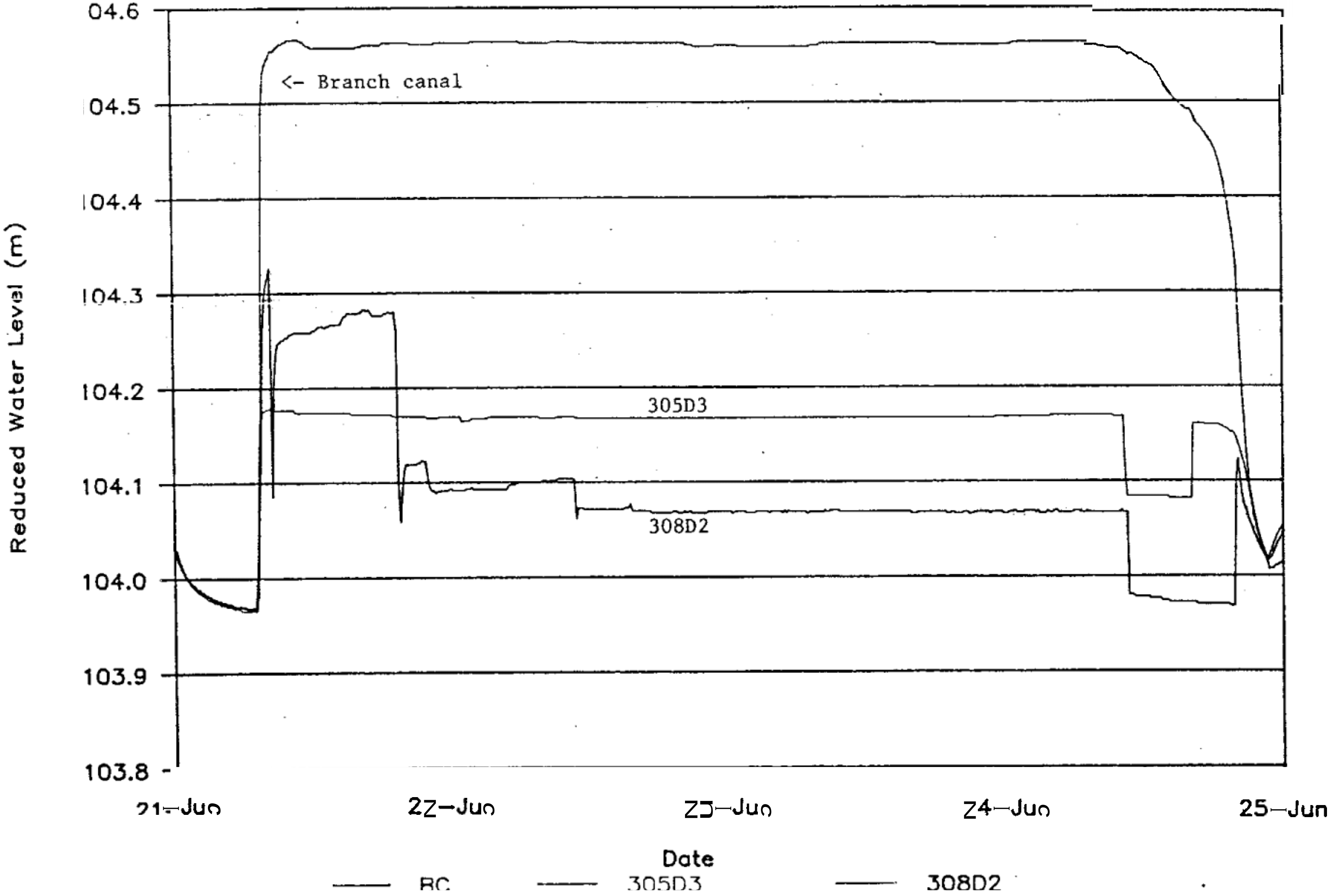


Figure IV 3

Kalankuttiya, Water level variations

near DB-Weir 1, 28 June to 01 July 1988

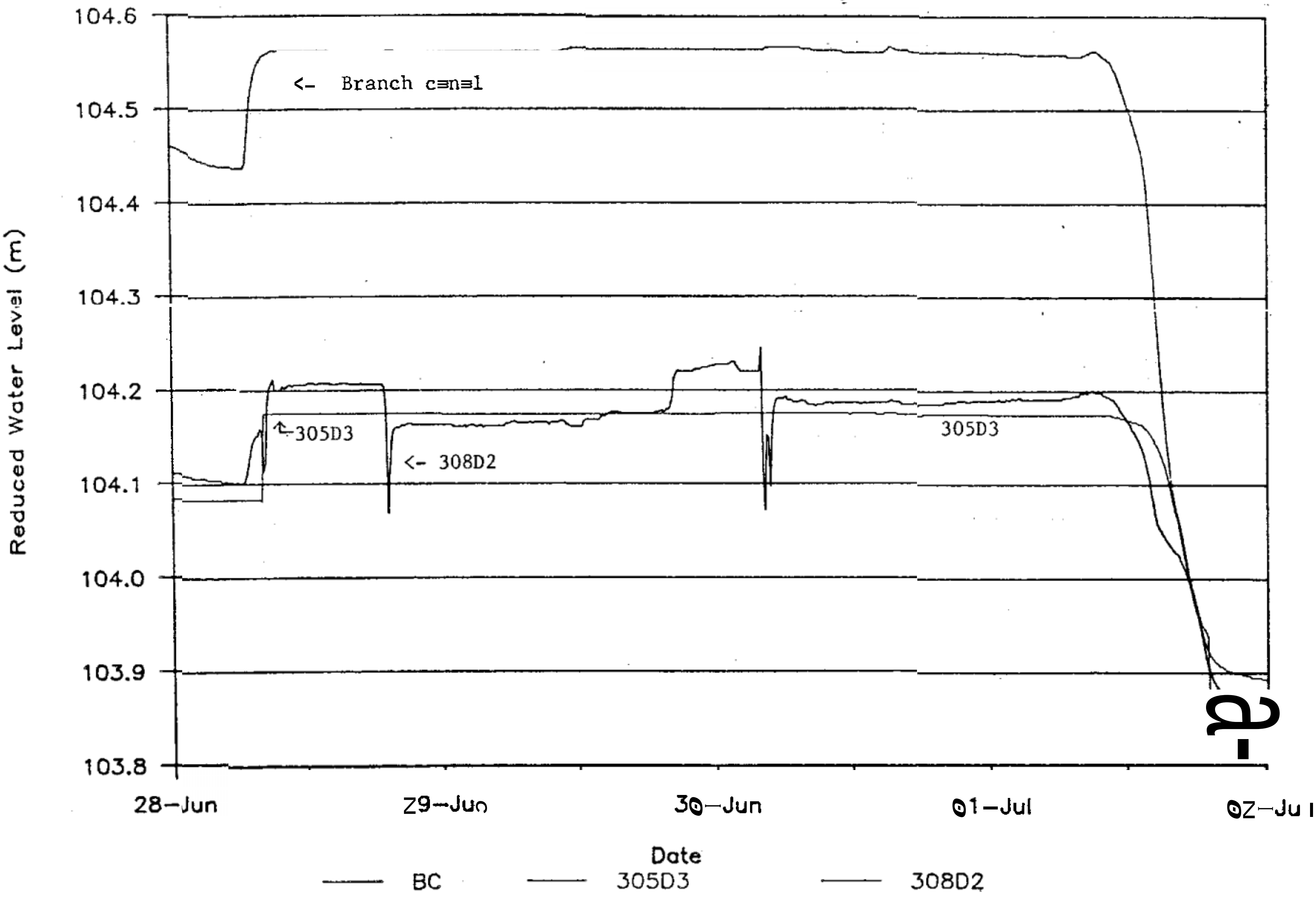
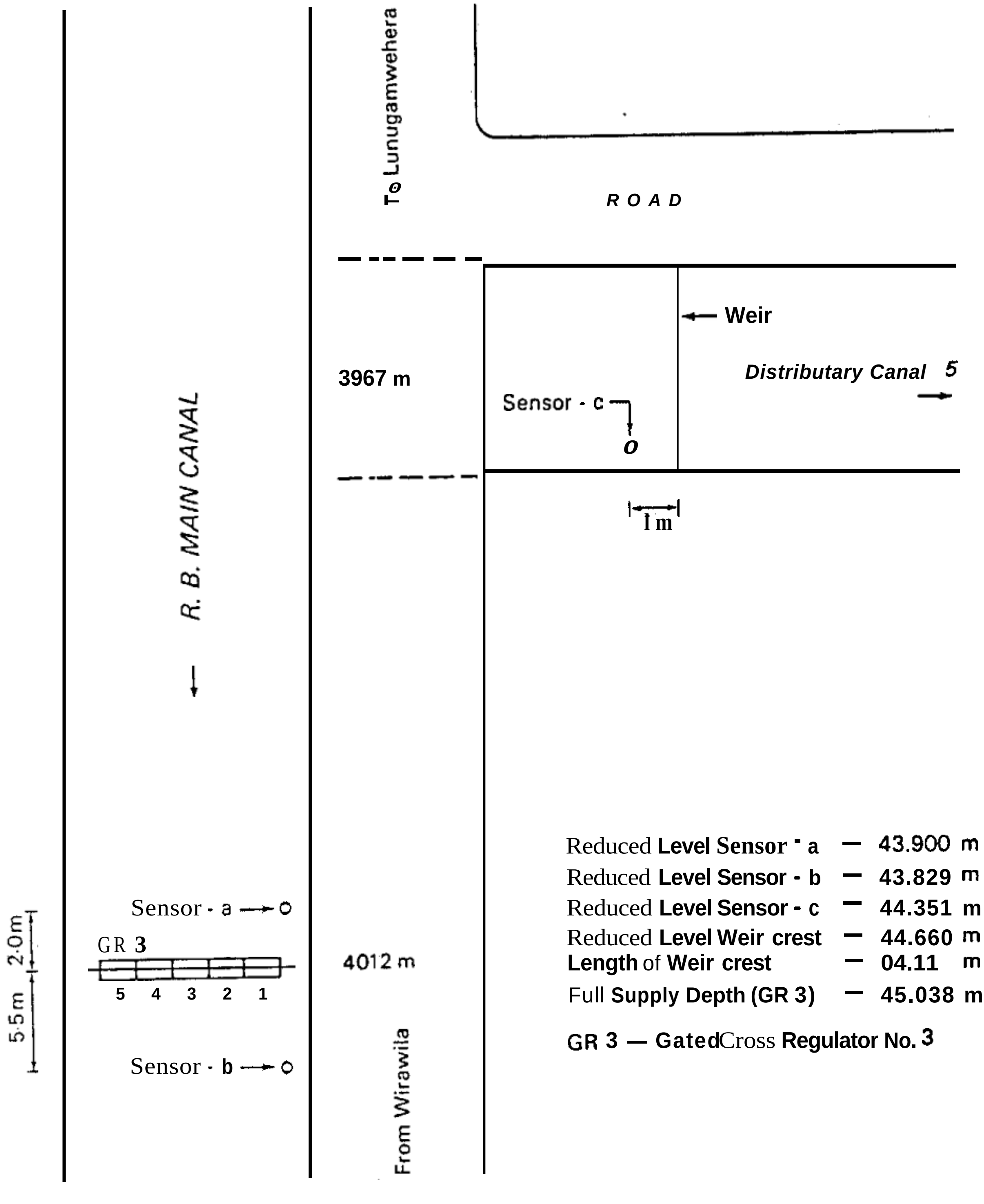


Figure 1V.34 Schematic diagram of data logging station at Distributary Canal (DC5), Tract 1, Kirindi Oya Right Bank Main Canal



Reduced Level Sensor - a — 43.900 m
Reduced Level Sensor - b — 43.829 m
Reduced Level Sensor - c — 44.351 m
Reduced Level Weir crest — 44.660 m
Length of Weir crest — 04.11 m
Full Supply Depth (GR 3) — 45.038 m

GR 3 — Gated Cross Regulator No. 3

Figure IV.35 Schematic diagram of data logging station Branch Canal 2 (BC2), Tract 5, Kirindi Oya Right Bank Main Canal

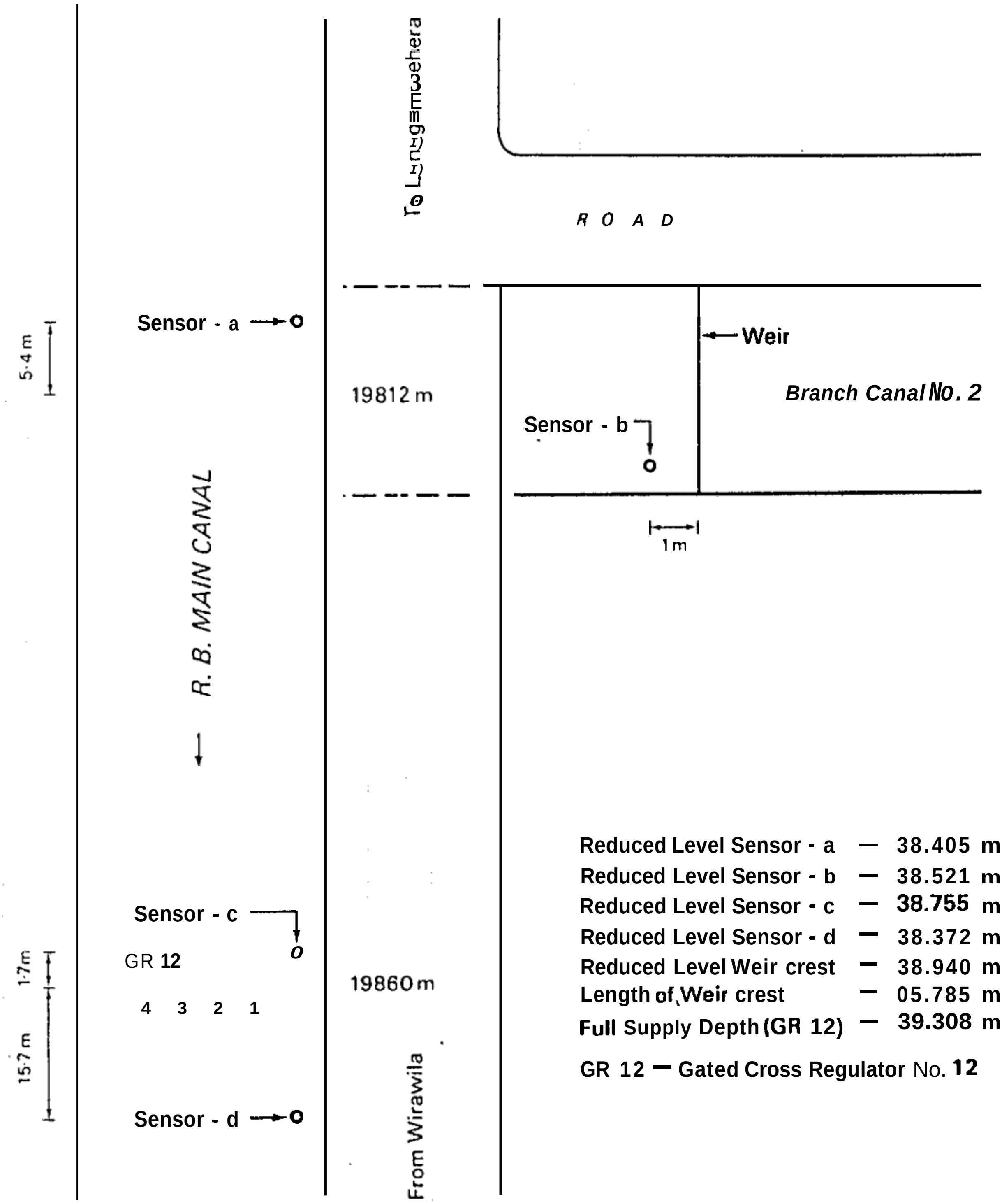


Figure IV.36 Sketch of DC5 and BC2 canal command areas and operational responsibilities of ID personnel, Kirindi Oya Right Bank Main Canal

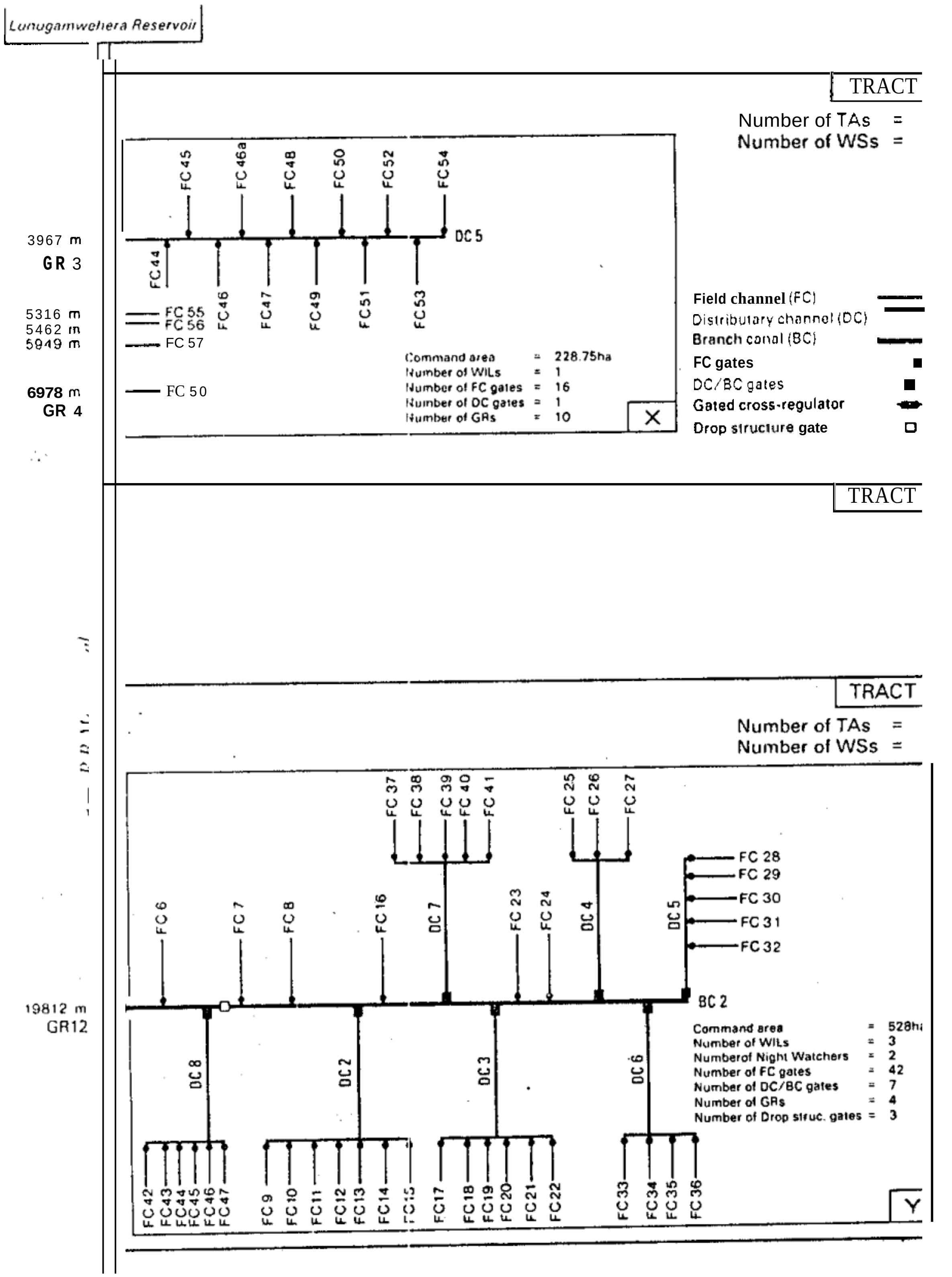


Table to be read in conjunction with Figure IV.36

Geographical distribution of staffing & structures under DC5, FC55, FC56, FC57 and FC58 command area in tract 1 (Region X in Figure IV.36) and BC2 command area in tract 5 (Region Y in Figure IV.36)

	Near DC5, Tract 1	Near BC2, Tract 5
Area of responsibility	egion X in figure IV.36	Region Y in figure IV.36
Command area (ha)	229	528
Technical Assistants (TA)	1 (also responsible for the whole of tract 1)	01 (also responsible for the whole of tract 5)
Work Supervisors (WS)	1 (also responsible for the whole of tract 1)	01 (the rest of tract 5 is managed by another WS)
Field Irrigators (FI)	01	05 (including two night watchers)
Number of field canal gates (FC)	16	42
Number of branch or distributory canal gates (BC/DC)	01	08 (including one BC gate)
Number of drop structure gates	-	03
Number of cross regulators	02 (five gated) GR3 & GR4	01 (four gated) GR12

Figure IV.37

SDA Lateral B
Calibration of 10 ft Parshall flume

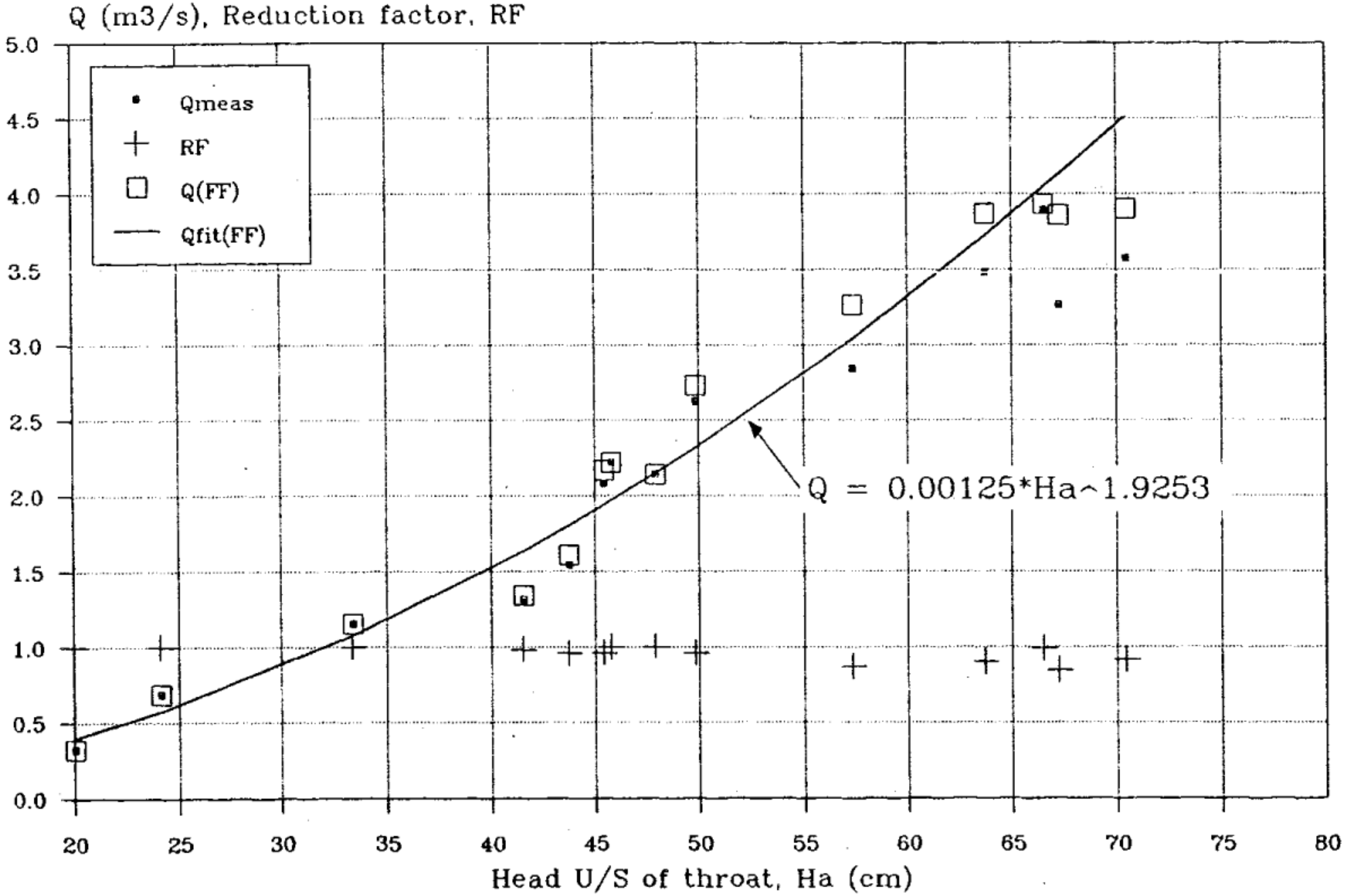
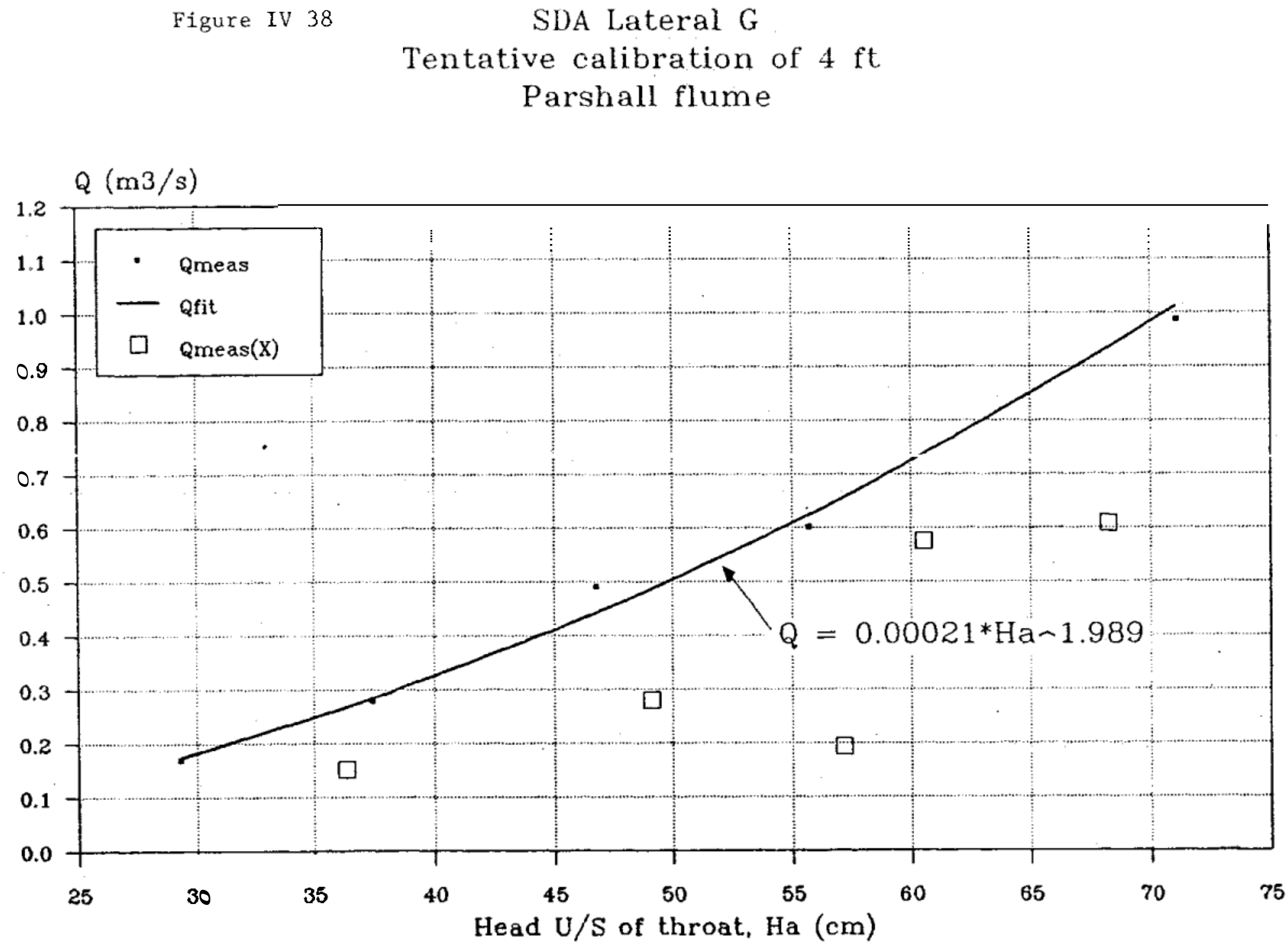


Figure IV 38



Qmeas(X) indicate measurements not considered for fitting the curve due to submergence

Figure IV.39 SDA Lateral B (10 ft Parshall flume)
Comparison of discharge assessed using
NIA table(QNIA) with IIMI gauging(Qmeas)

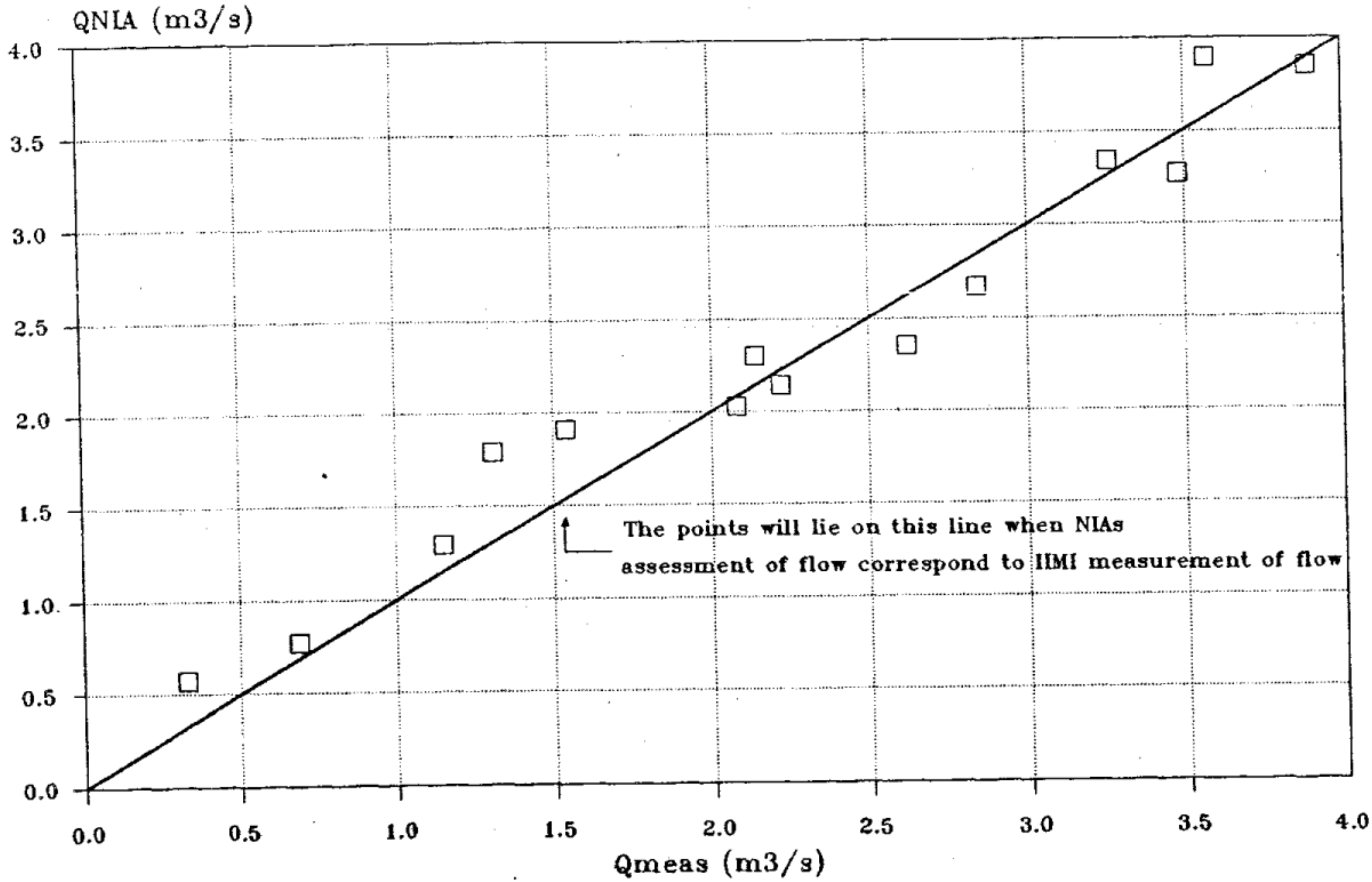
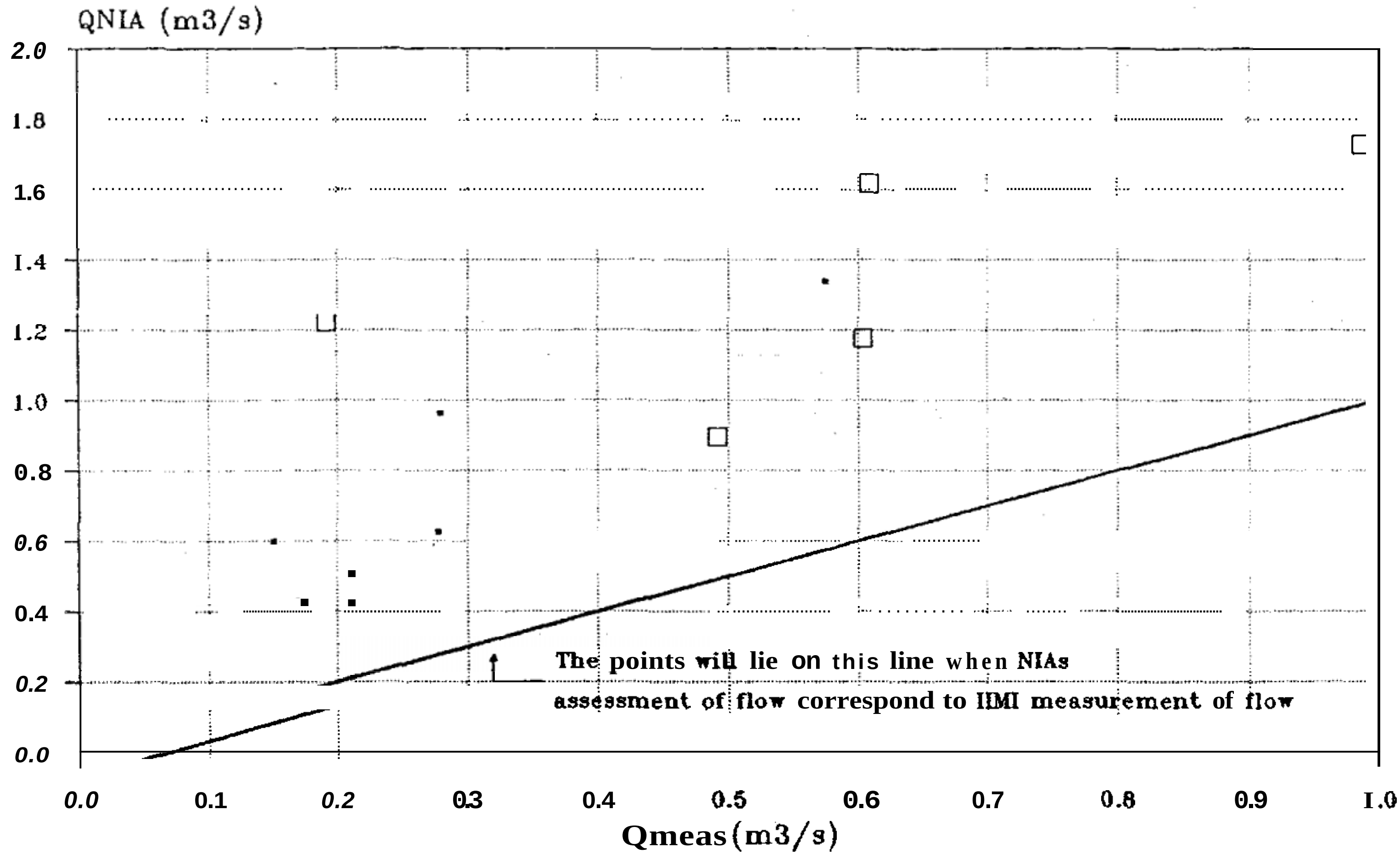
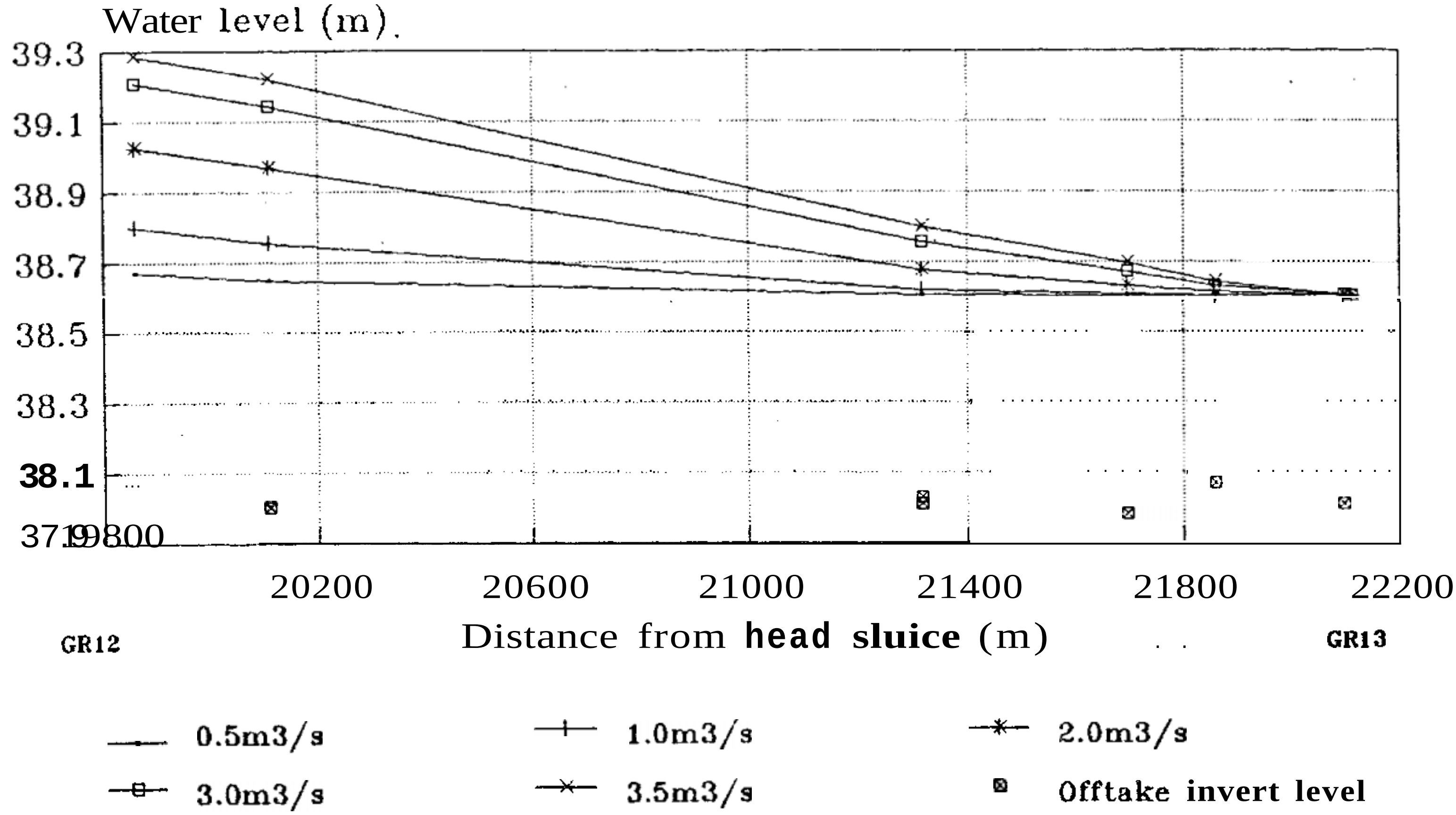


Figure IV.40 SDA Lateral G (4 ft Parshall flume)
Comparison of discharge assessed using
NIA table(QNIA) with IIMI gauging(Qmeas)



□ Points not considered for fitting the tentative calibration curve due to submergence

Figure IV.41 Kirindi Oya RB Main Canal: Water surface profile in reach GR12–GR13 assuming water level at **GR13** maintained at FSD



* **Full Supply Depth (FSD)** at GR13=38.60m

Figure IV.42 Simulated range of water level variation at. the offtakes while level at downstream cross regulator varies.

Reach GR12-GR13, Kirindi Oya RBMC

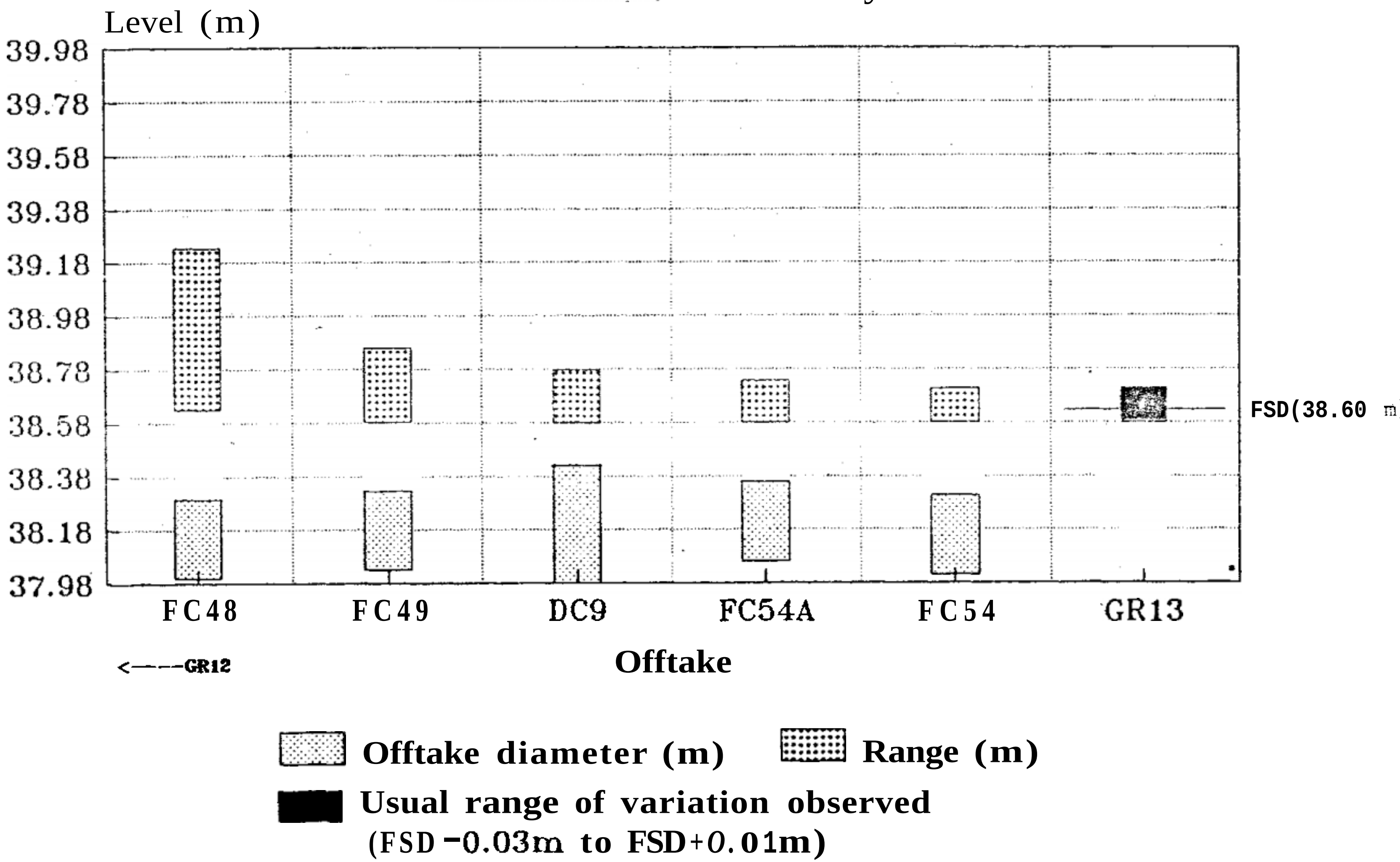


Figure IV C3 Relative range of water level variation expected above offtake invert levels, Reach GR12-GR13, Kirindi Oya RBMC

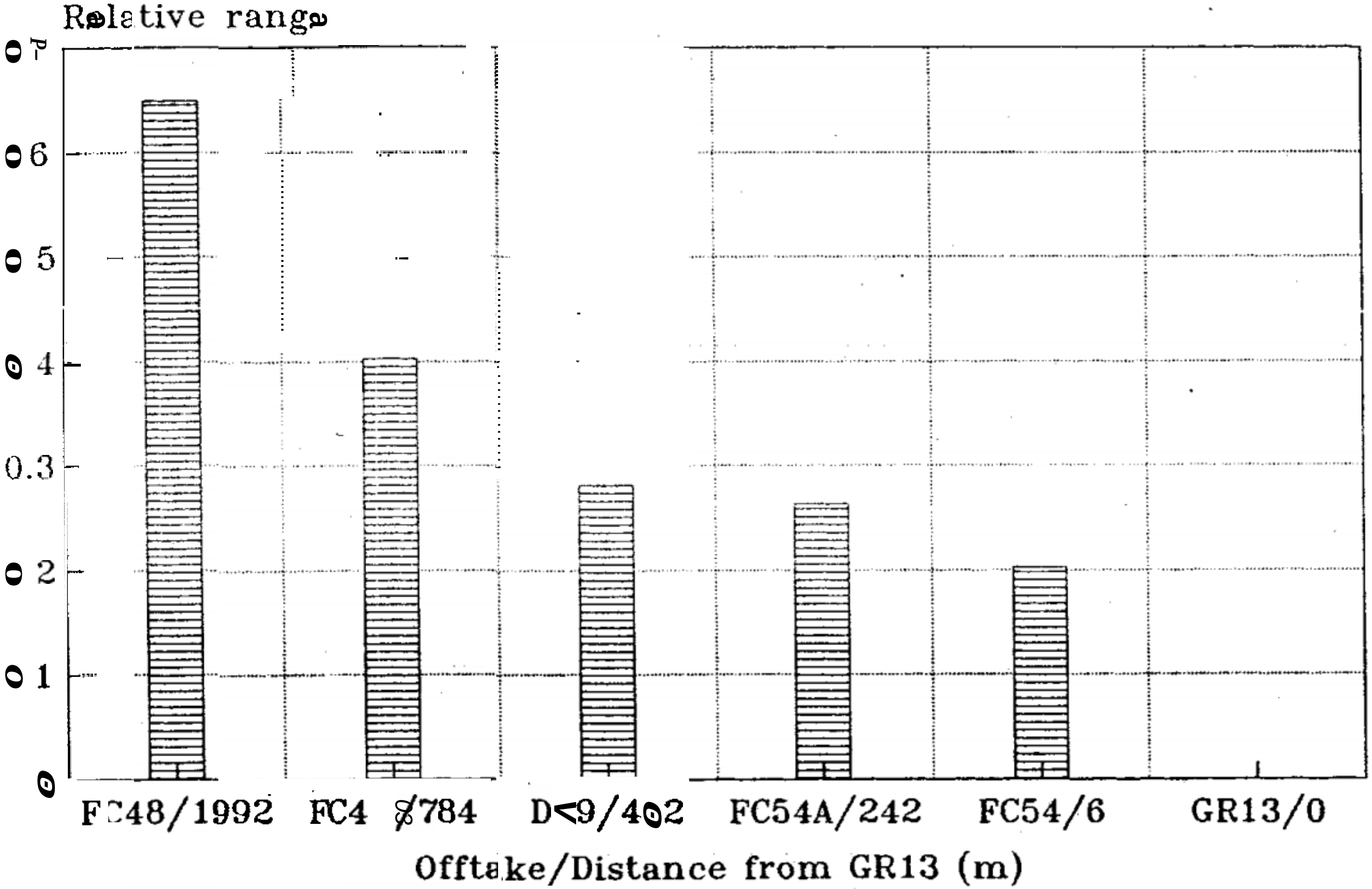
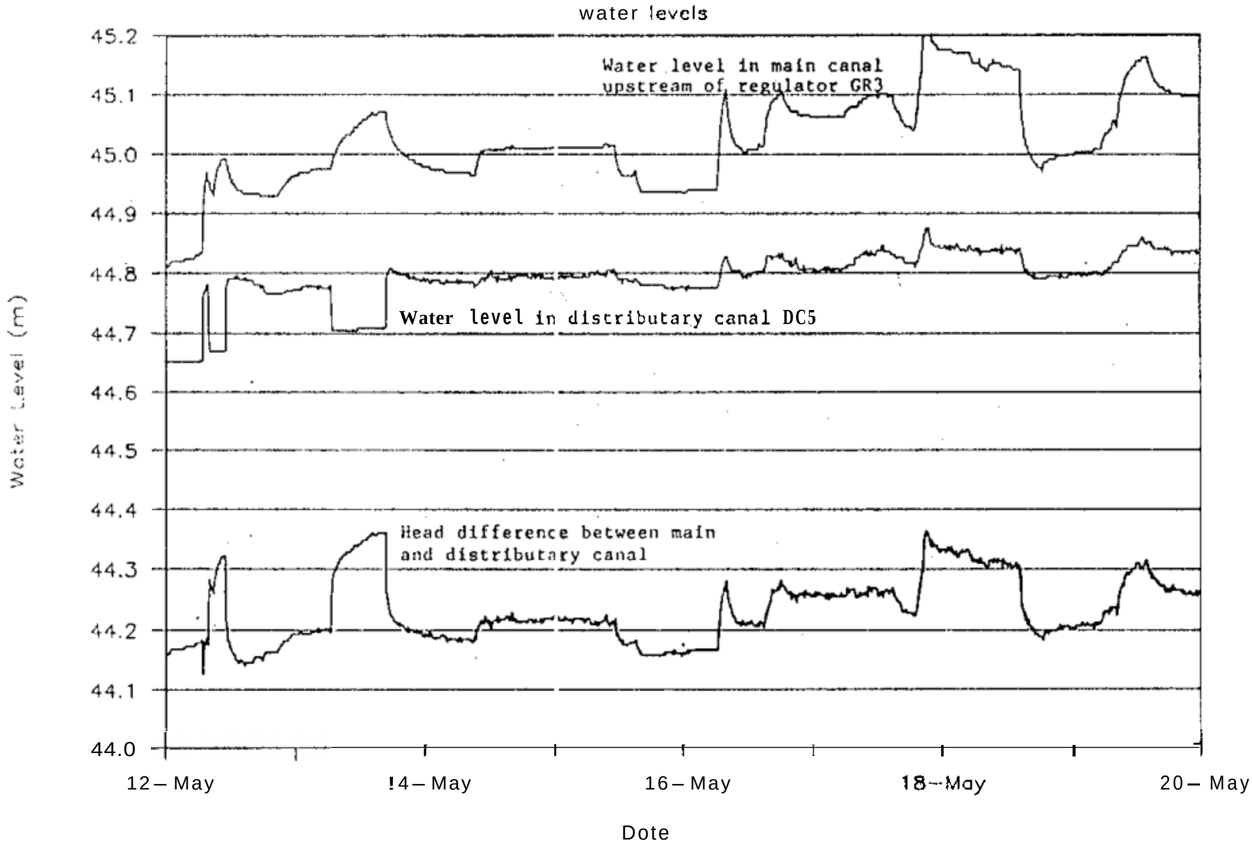


Figure IV.44 Kirindi Oya Right Bank Main Canal : Water levels and gate interventions near DC5, 12-20 May 1988



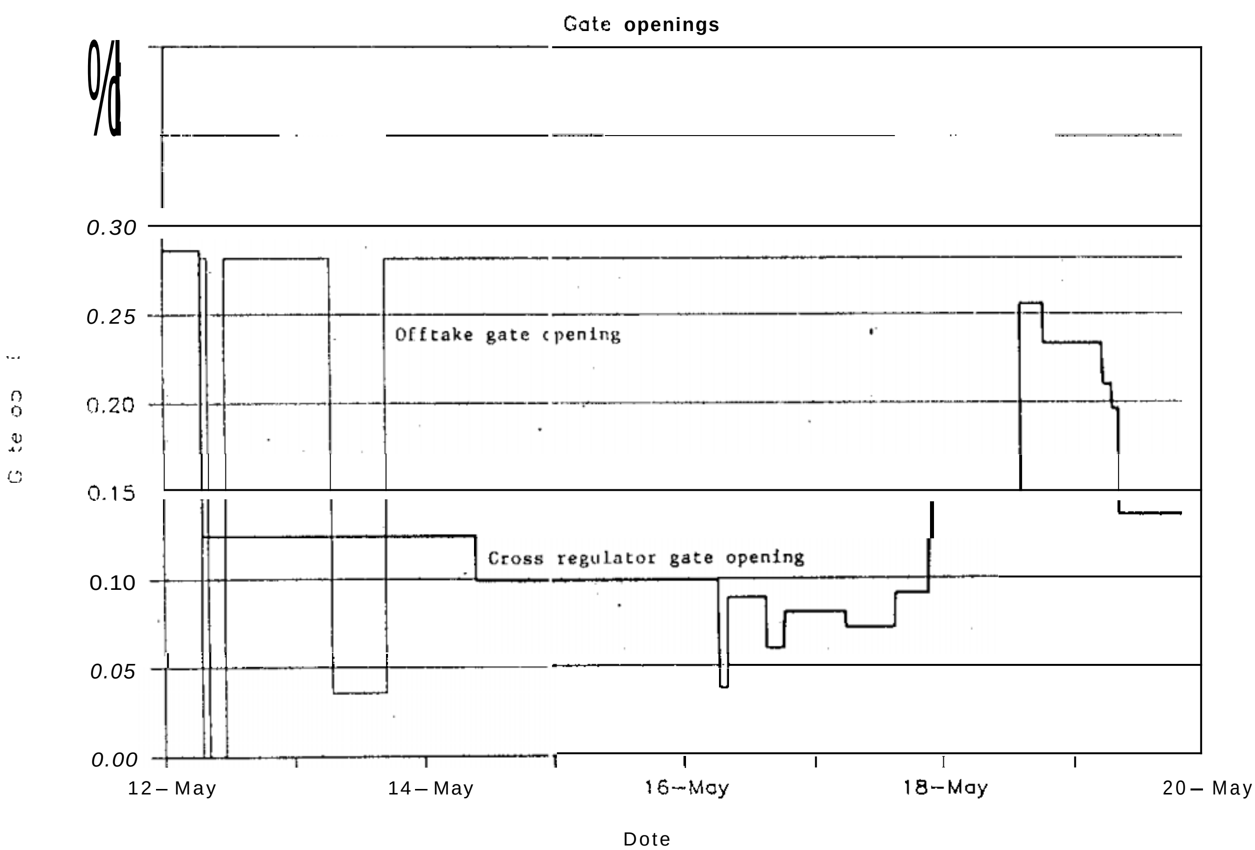


Figure IV.45 Kirindi Oya Right Bank Main Canal : Frequency distribution of water levels in Main Canal at GR3

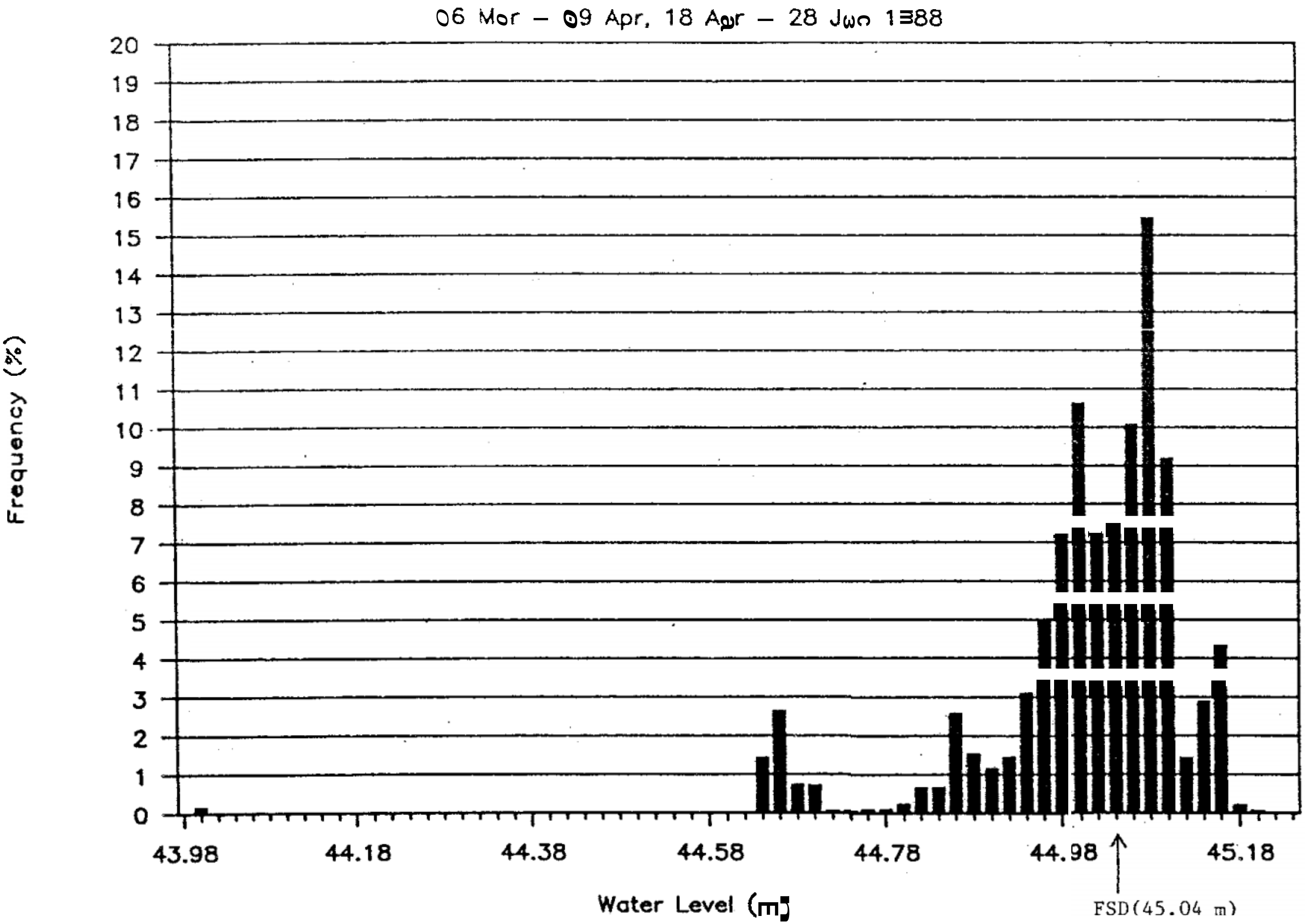


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Figure IV.46 Kirindi Oya Right Bank Main Canal : Cumulative Frequency distribution of water levels in Main Canal at GR3

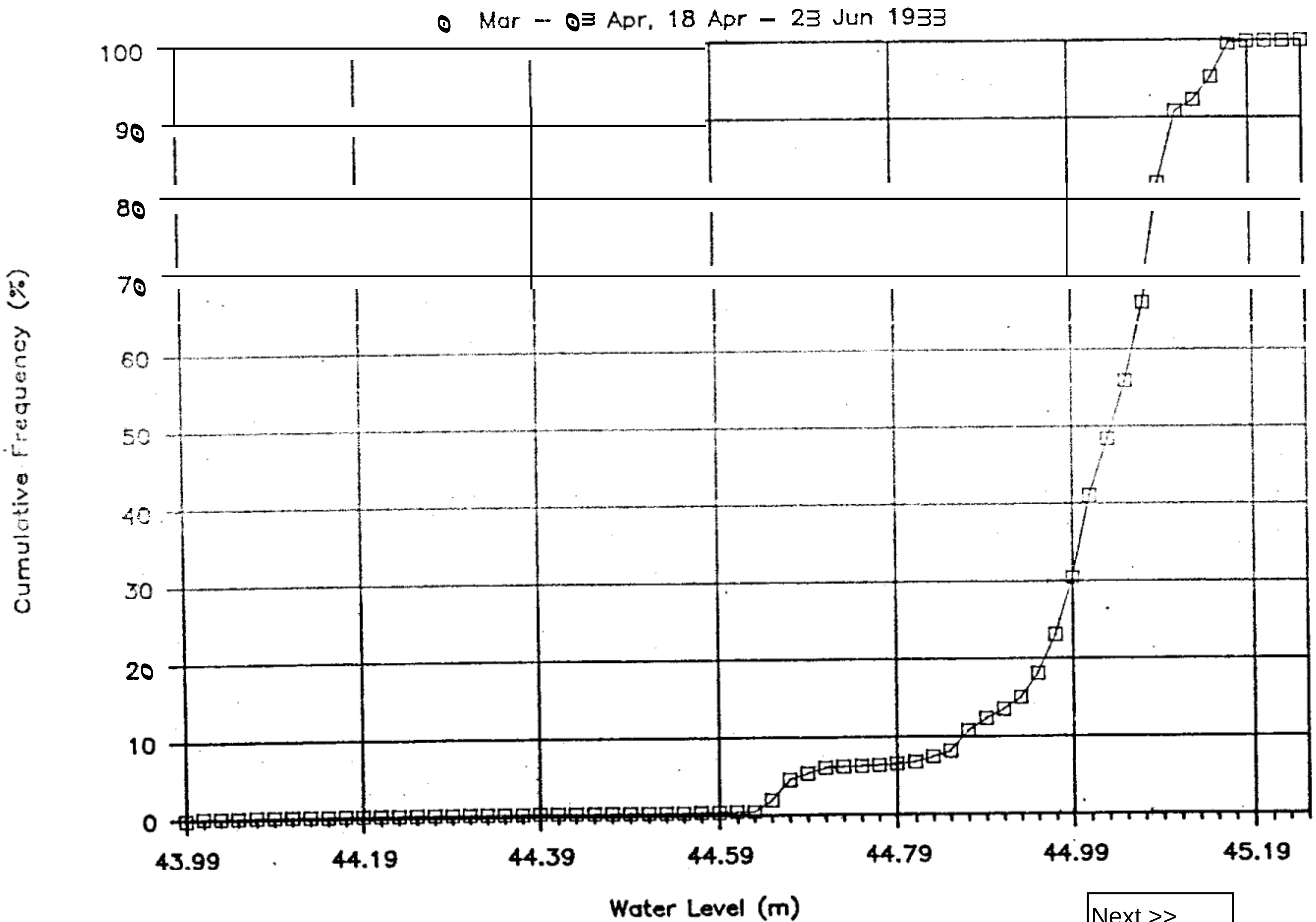

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Figure IV.47 Kirindi Oya Right Bank Main Canal : Frequency distribution of water levels in Main Canal at GR12

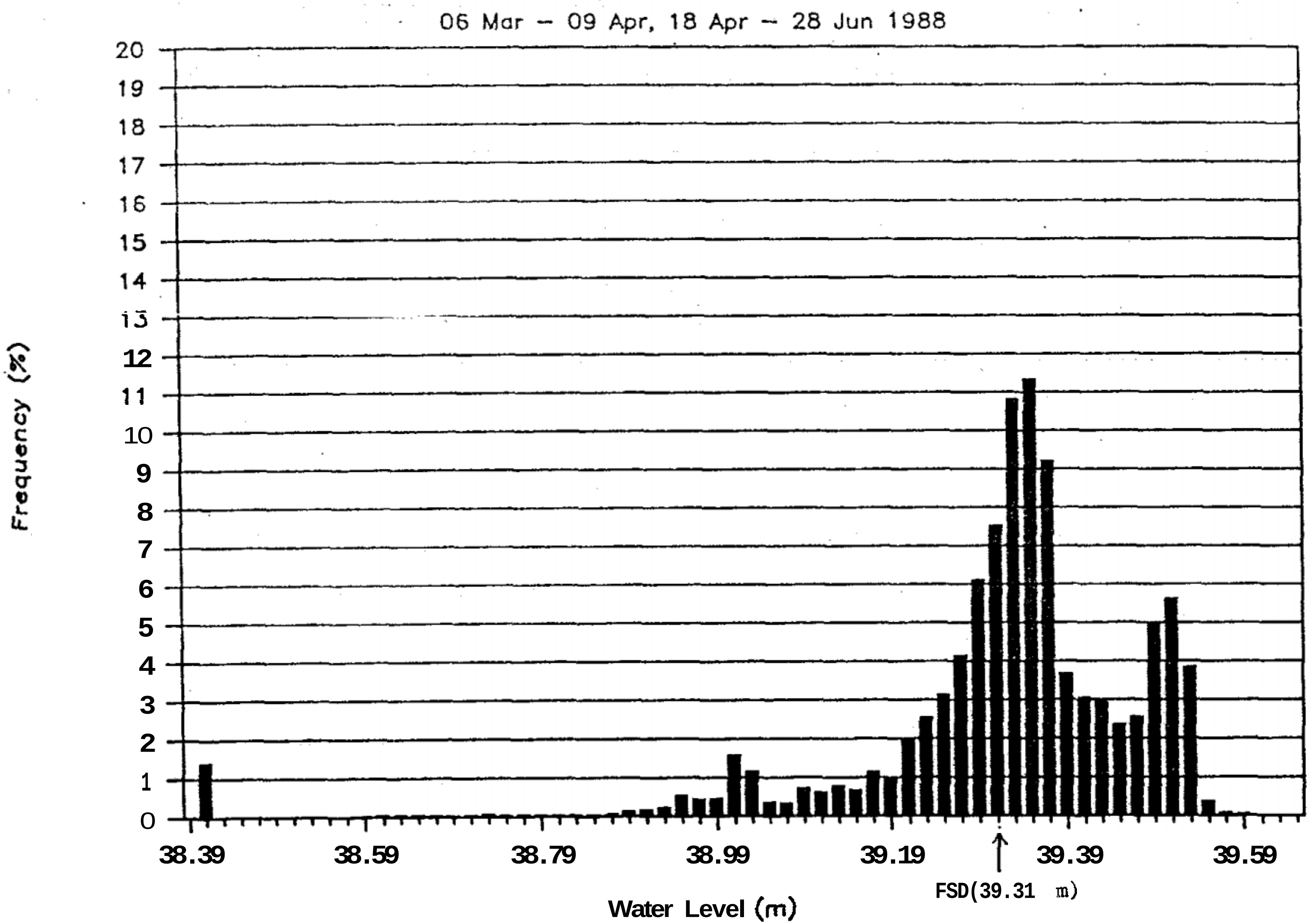


Figure IV.48 Kirindi Oya Right Bank Main Canal : Cumulative Frequency distribution of water levels in Main Canal at GR12

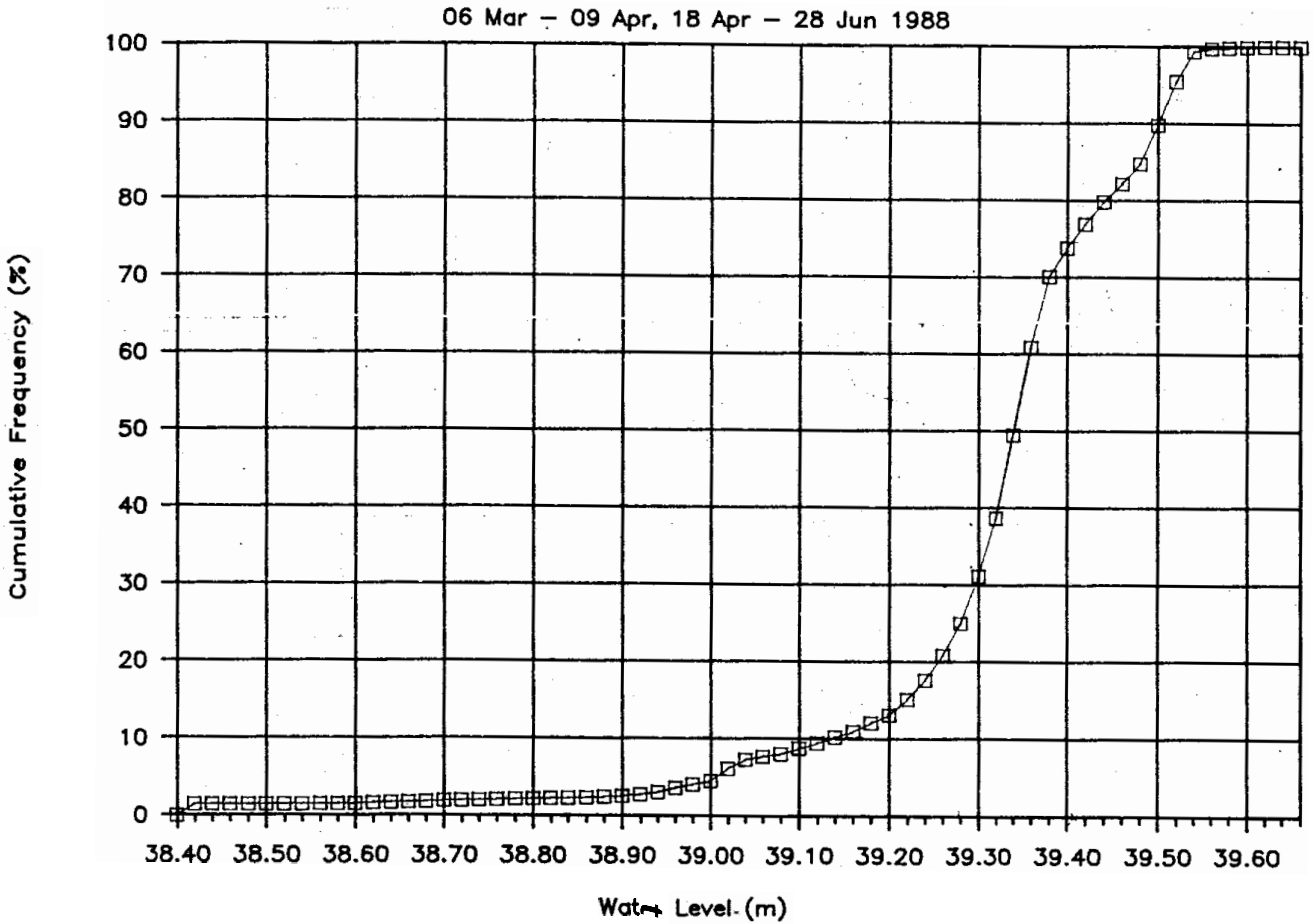
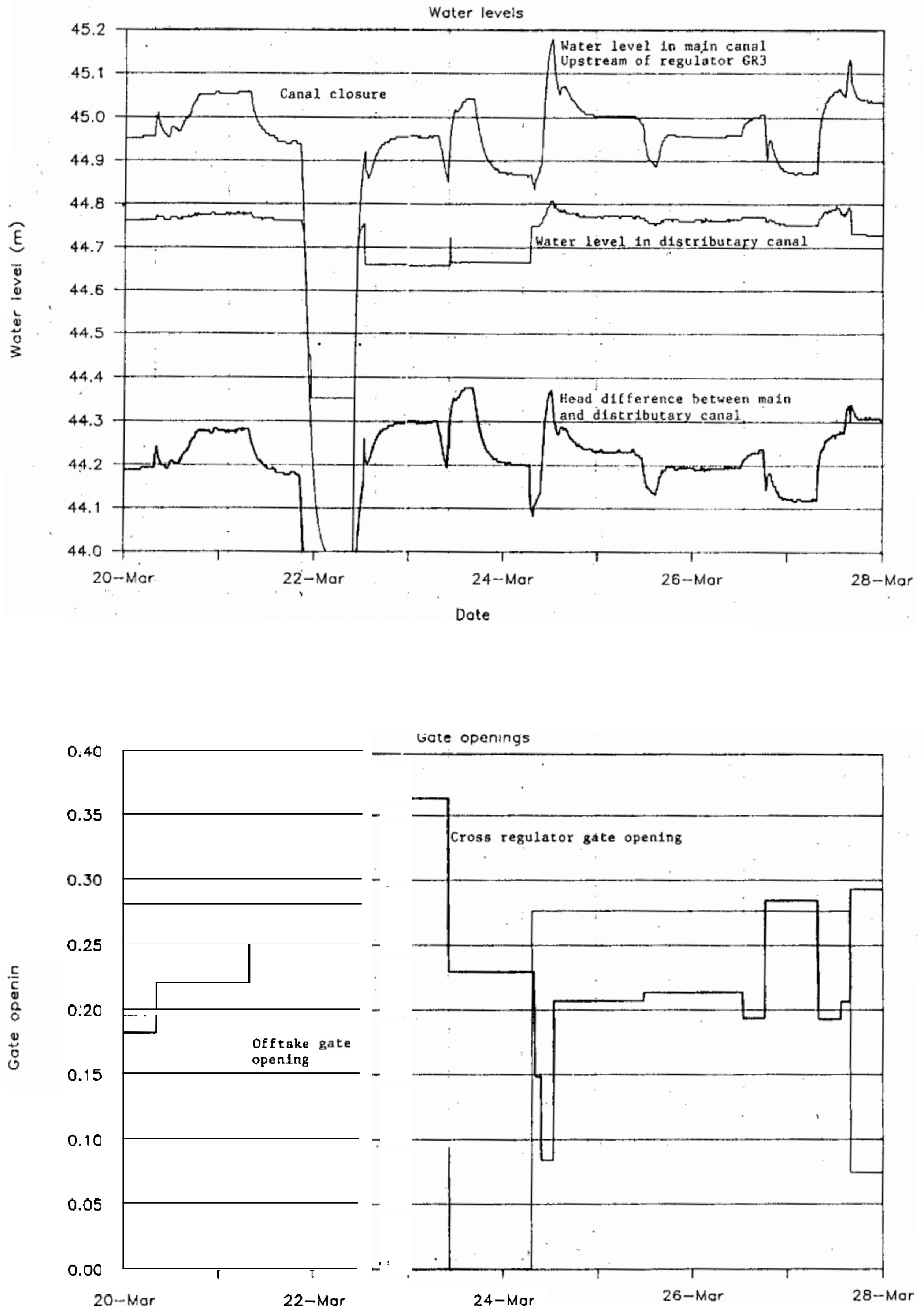
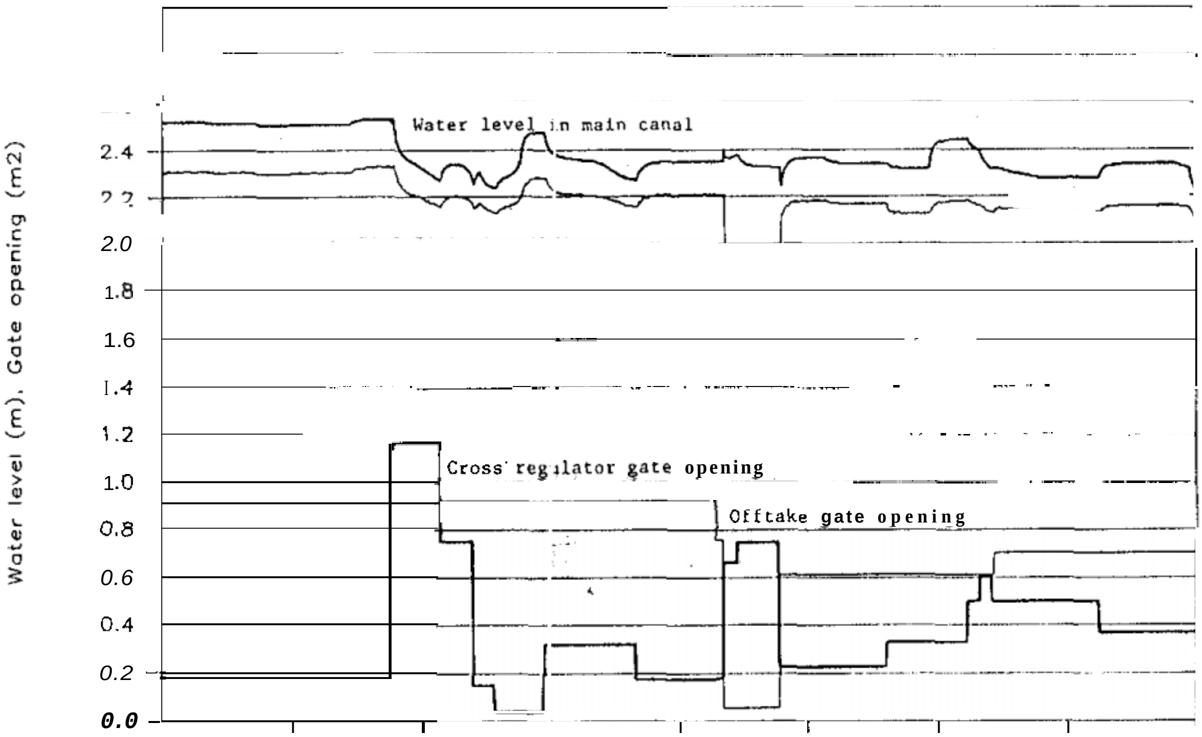


Figure IV.49

Kirindi Oya Right Bank Main Canal : Water levels and gate interventions near DC5, 20-28 March 1988





Flow estimated by two different methods

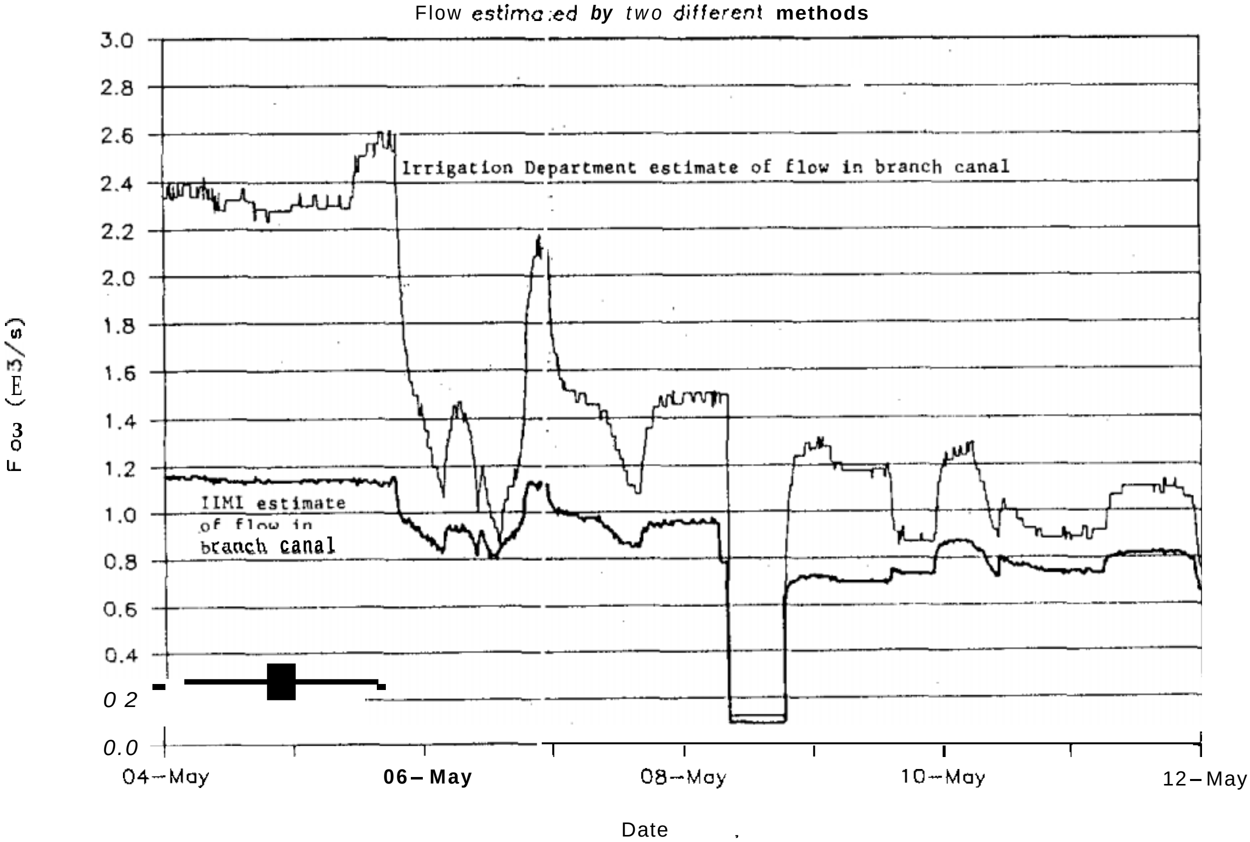
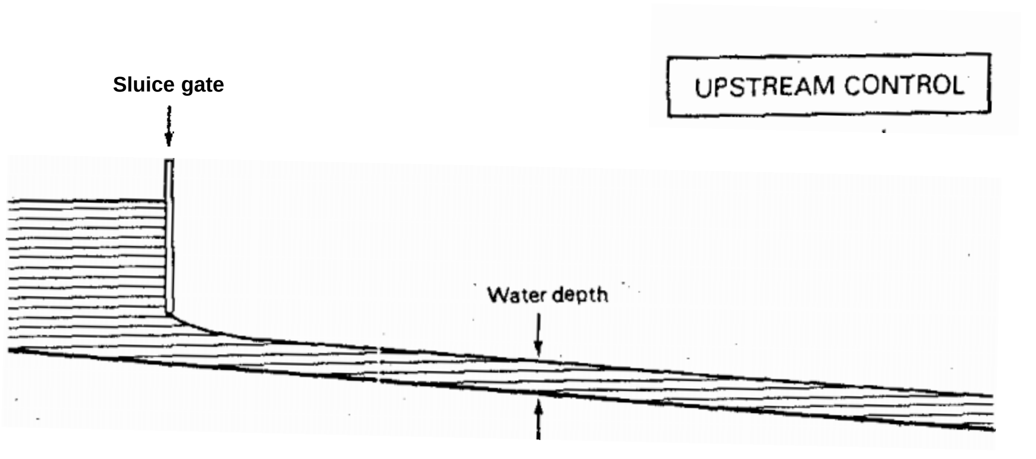
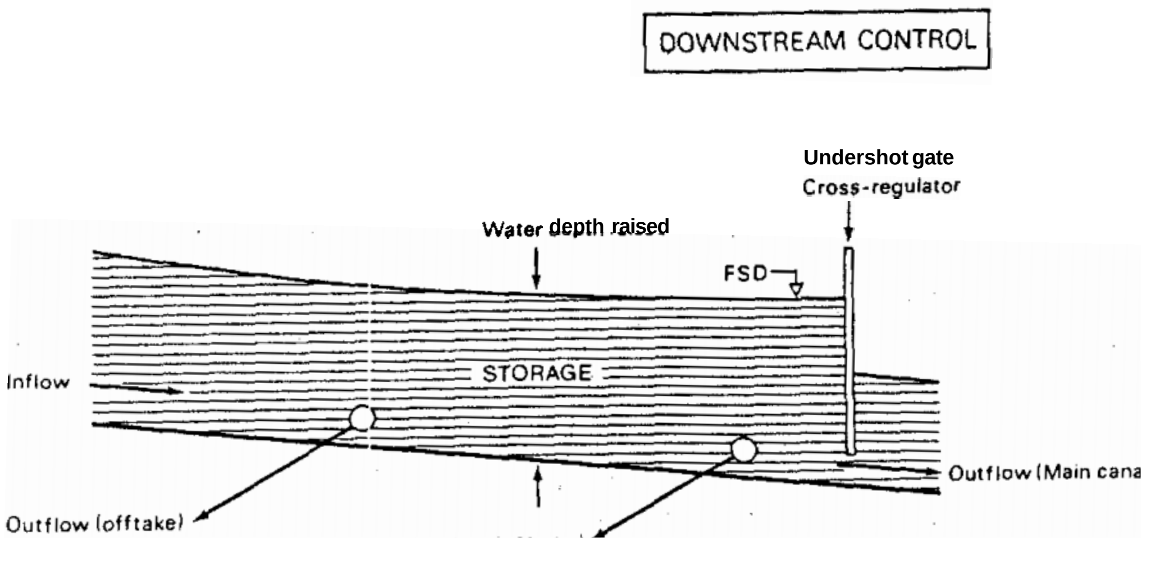


Figure IV.51 Water surface profiles along a canal: two typical situations

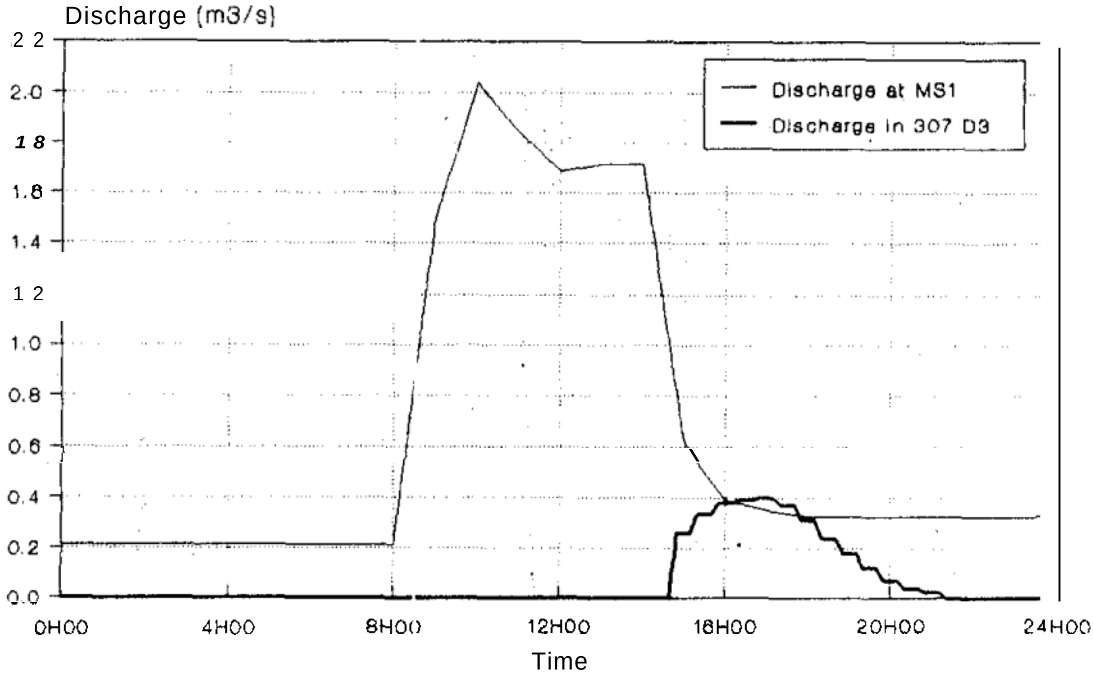


Water depth/ f low control through **gate** operation



Water depth /storage control through gate operation

Figure LV.52 **Kalankuttiya branch canal: Special issue of water to thg tail end on 20 May 88 Discharges at MS1 and in 307 D3**



Volume delivered at MS1 = 41,087 m3 (08H00 - 16H00)
Volume ***delivered*** *to 307 D3 = 5,651 m3 (14H40 - 21H20)*

Kalankuttiya branch canal
Water level variation at duck-bill weir 1 on 20 May 1988

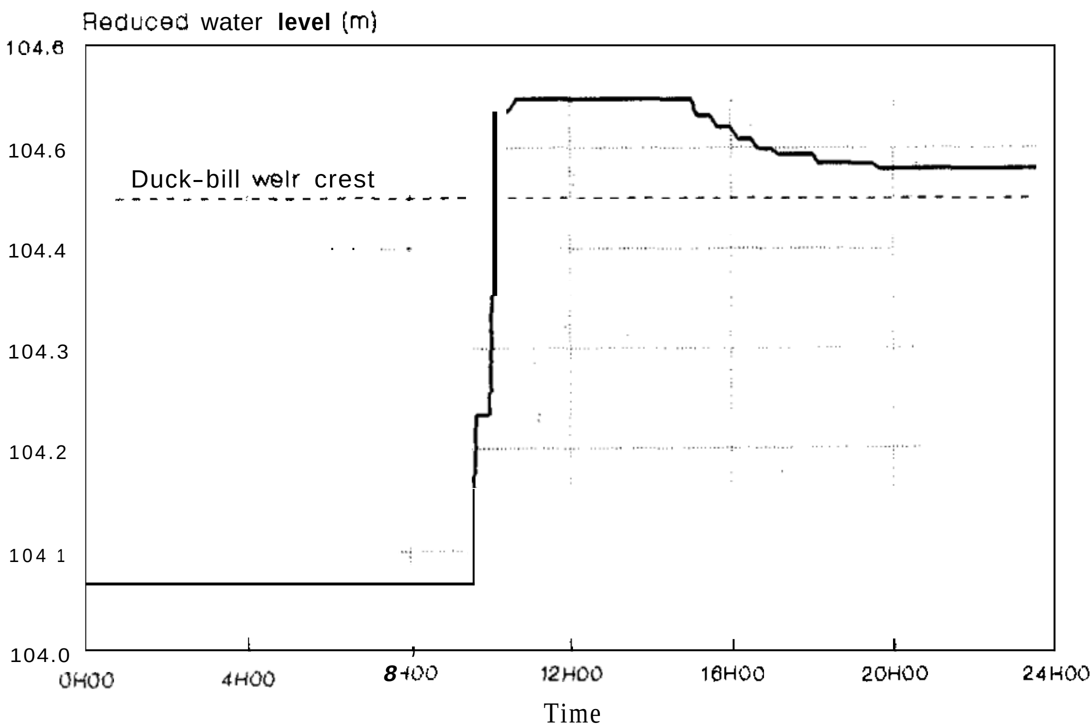


Figure IV.53 *Kirindi Oya* **RBMC**: *Observations at cross regulators* **GR3** *and GR12 of the propagation of a wave released at 06H30 from the dam*

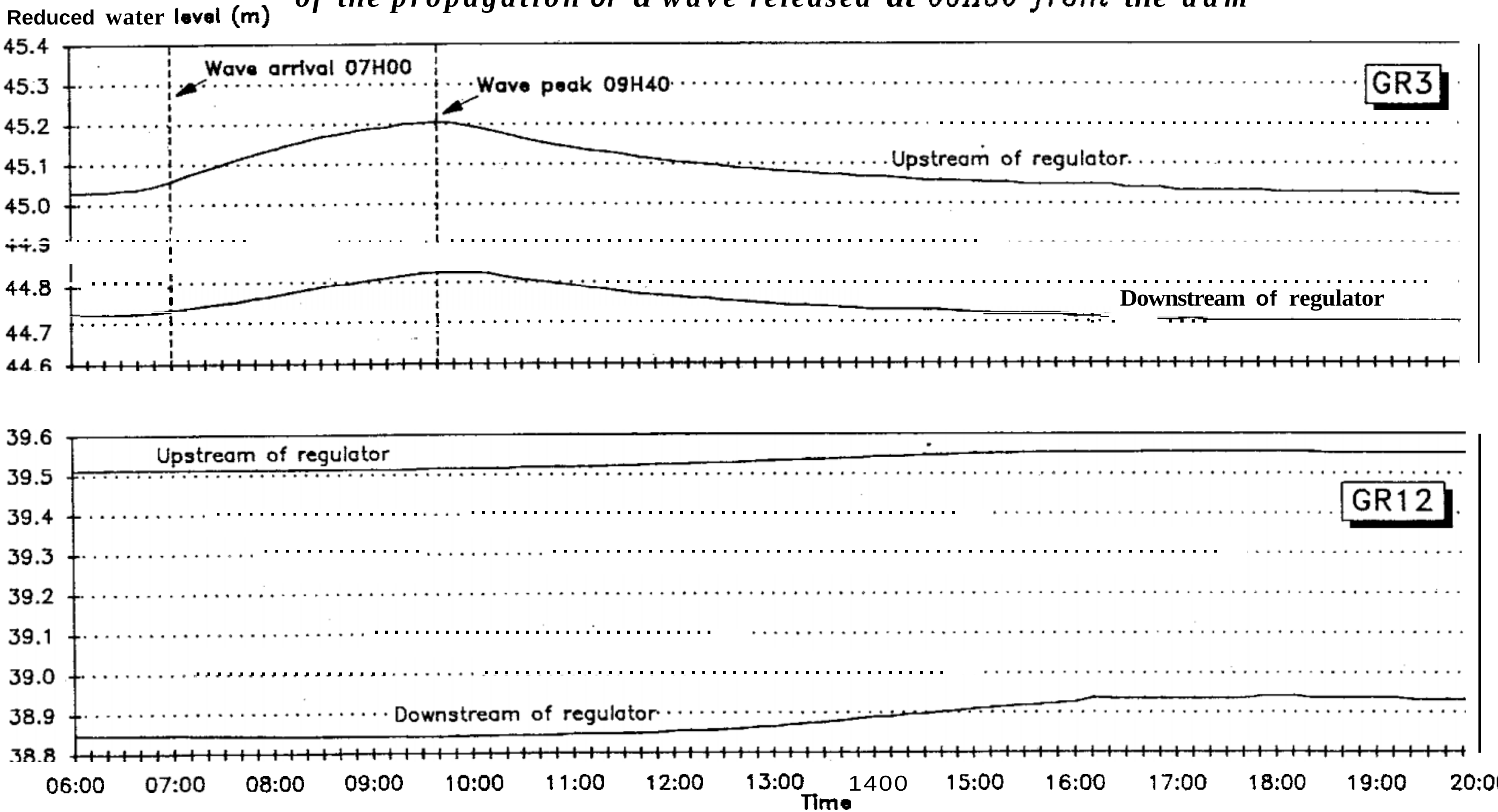
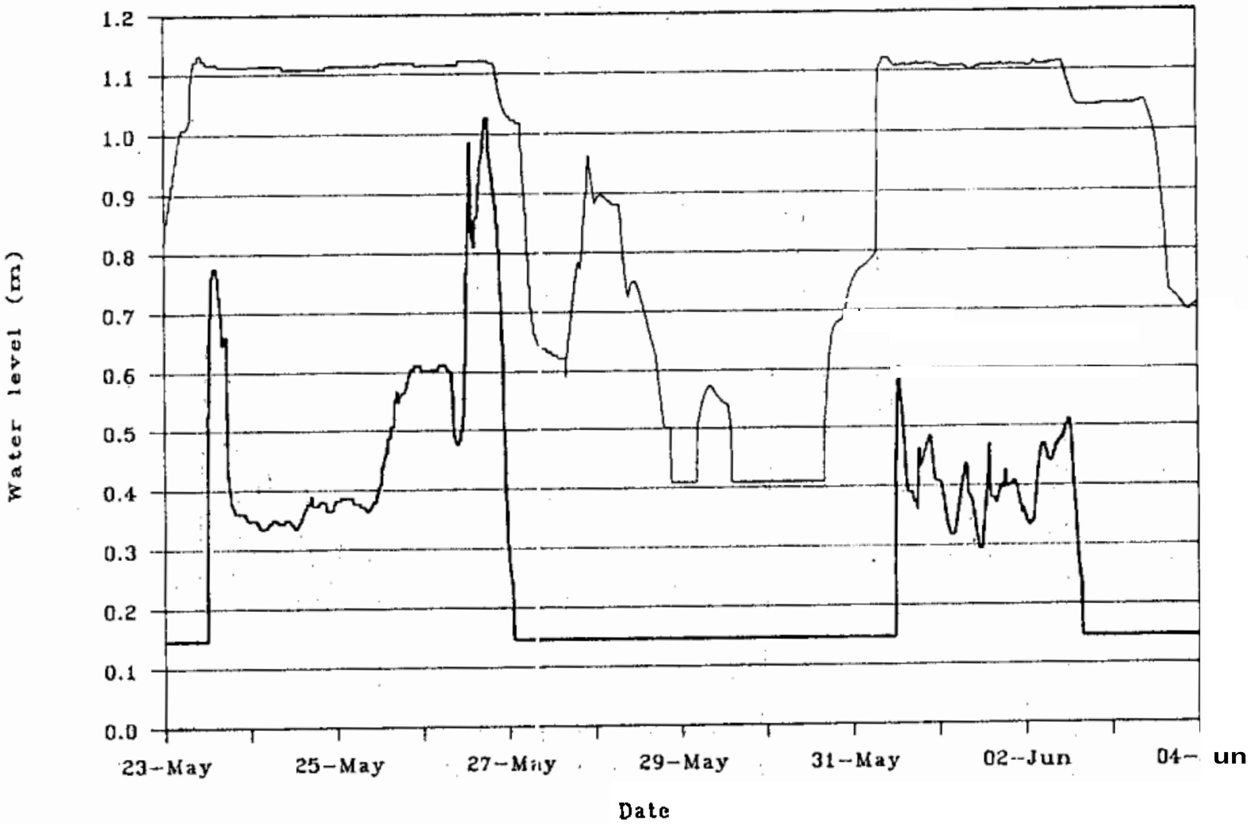


Figure V.1

Kalankuttiya: branch canal water levels recorded every 10 minutes by the dataloggers at DBW1 and tailend during 4 typical rotations



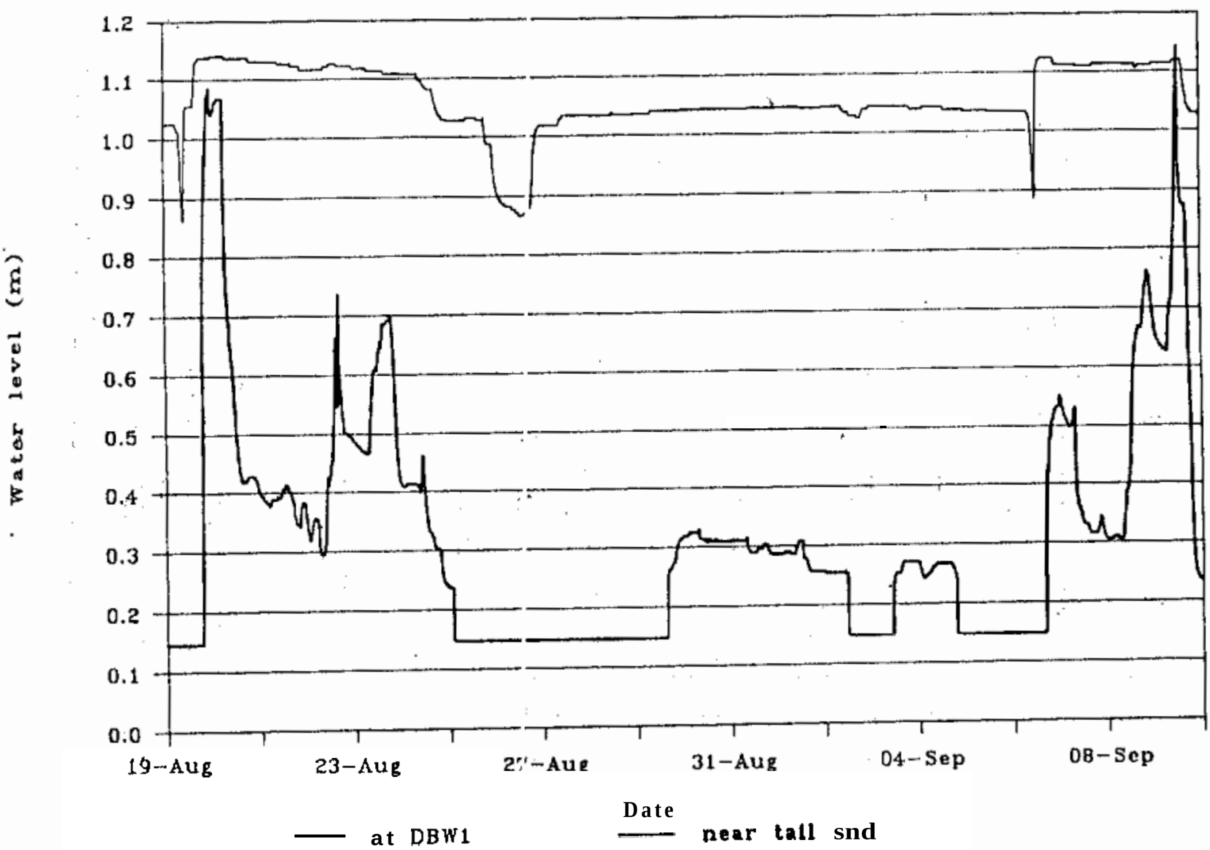
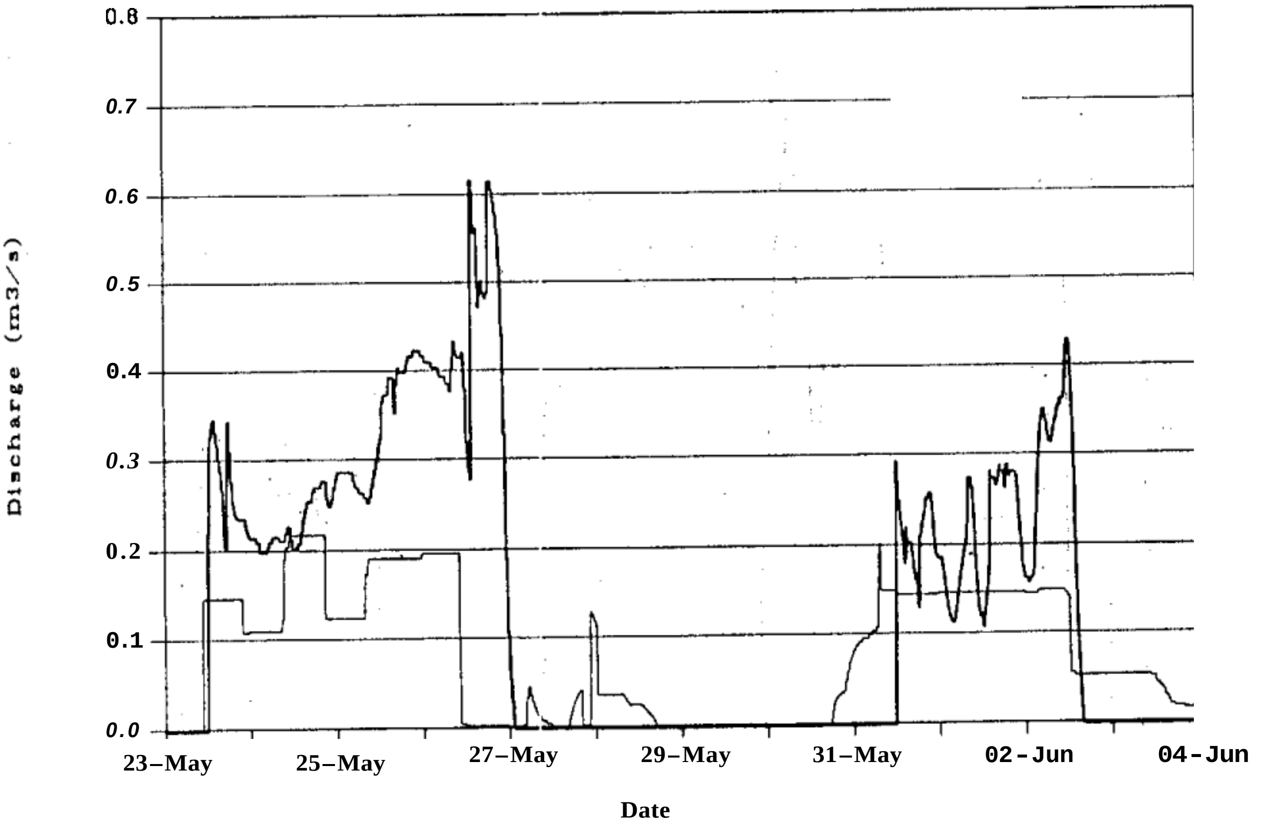


Figure V.2

Kalankuttiya: Discharges into distributary canals 305D3 and 307D3 during the rotations R1, R2, R11 and R12



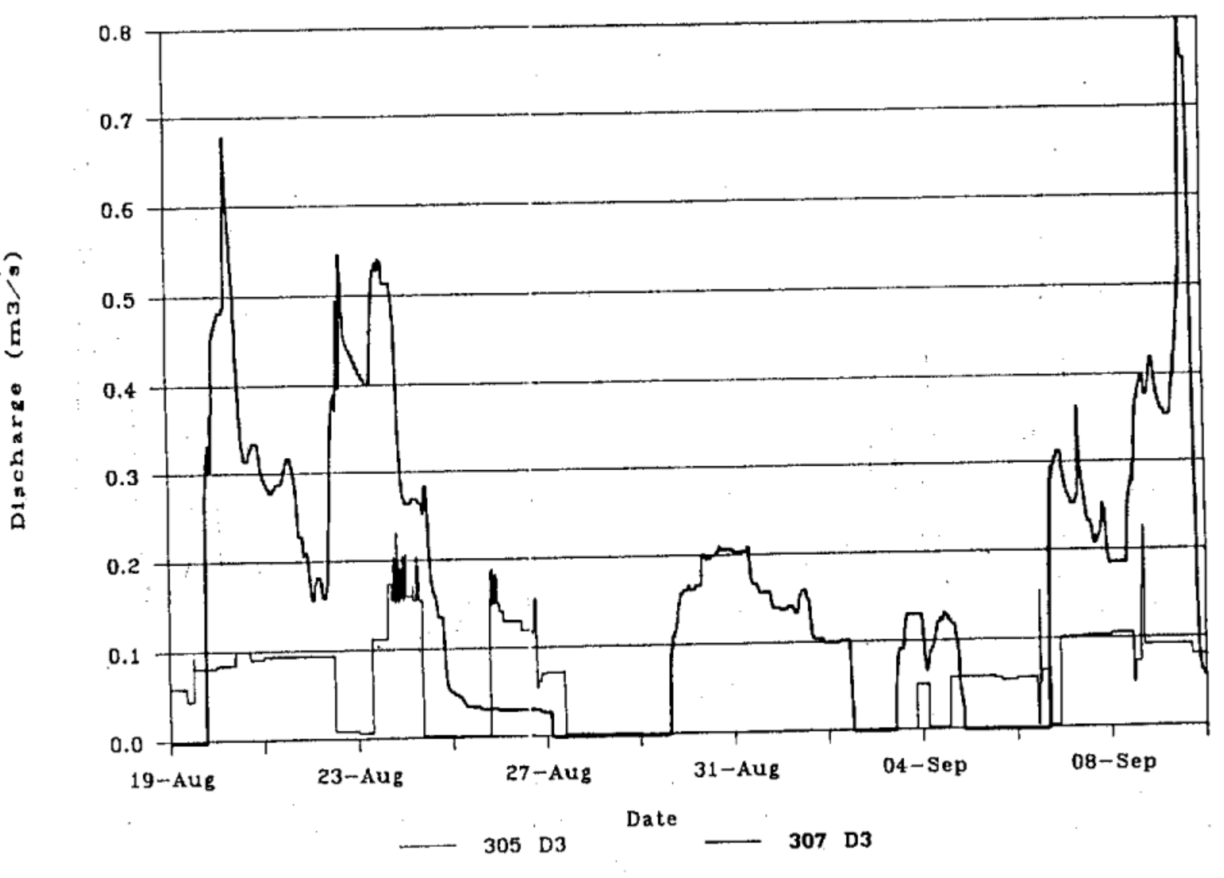


Figure V.3 Kalankuttiya branch canal: Daily range of water level variation near duck-bill weir 1, 09 May to 24 Sep 1988

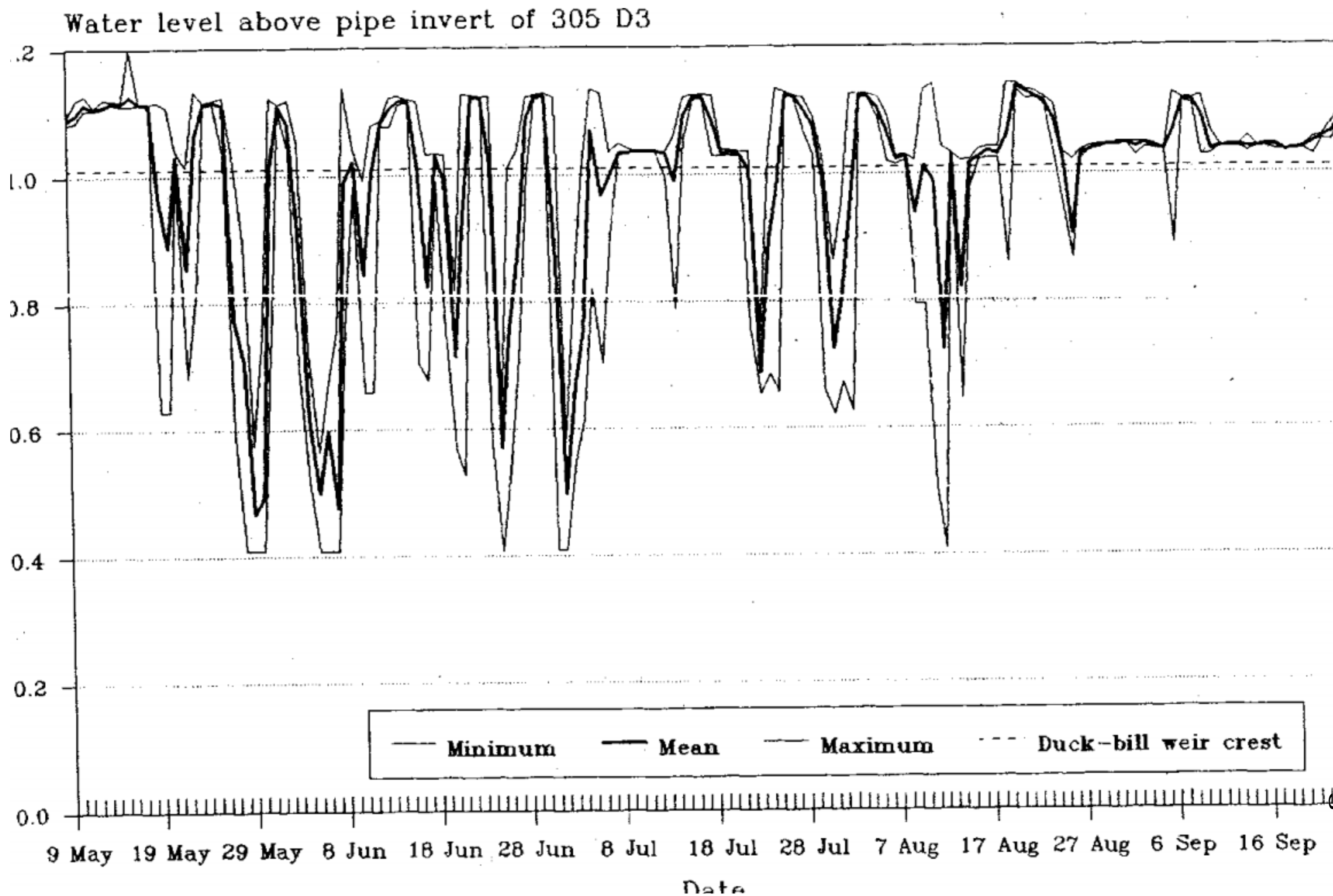
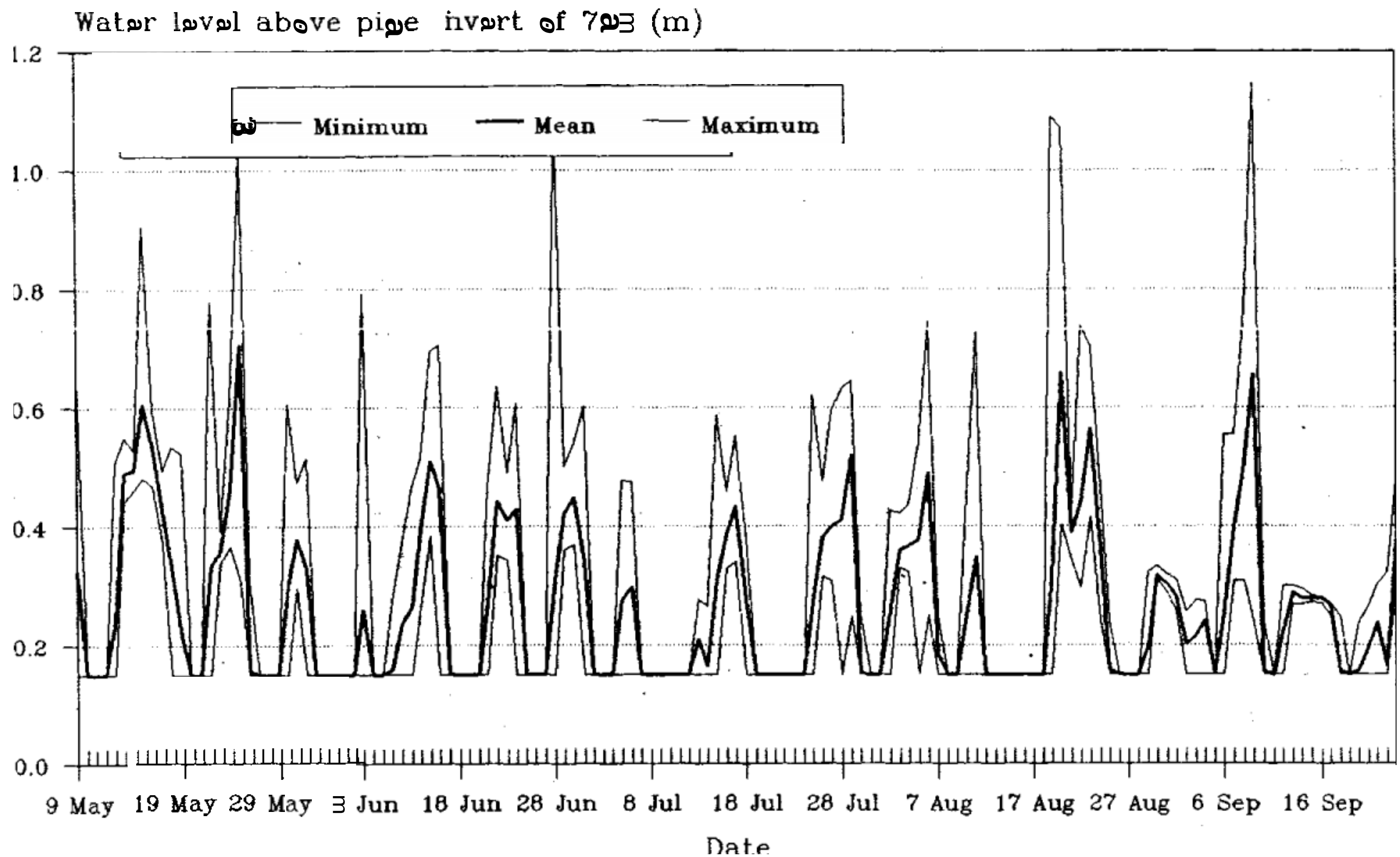
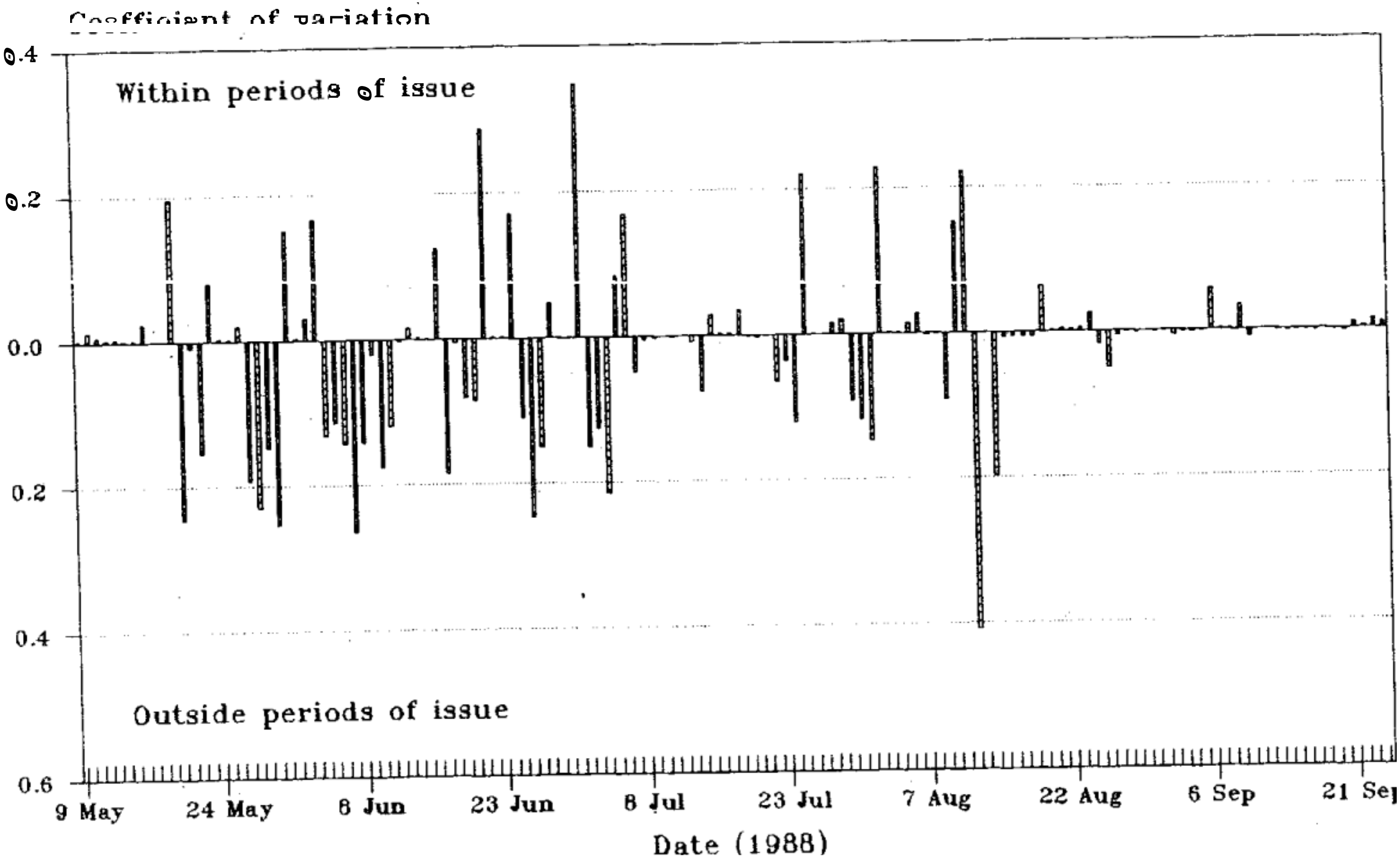


Figure V.4 Kalankuttiya branch canal: Daily range of water level variation near the tail end, 09 May to 24 Sep 1988



When the water level falls below 0.15m it is assumed that there is no flow in the branch canal at the tail end.

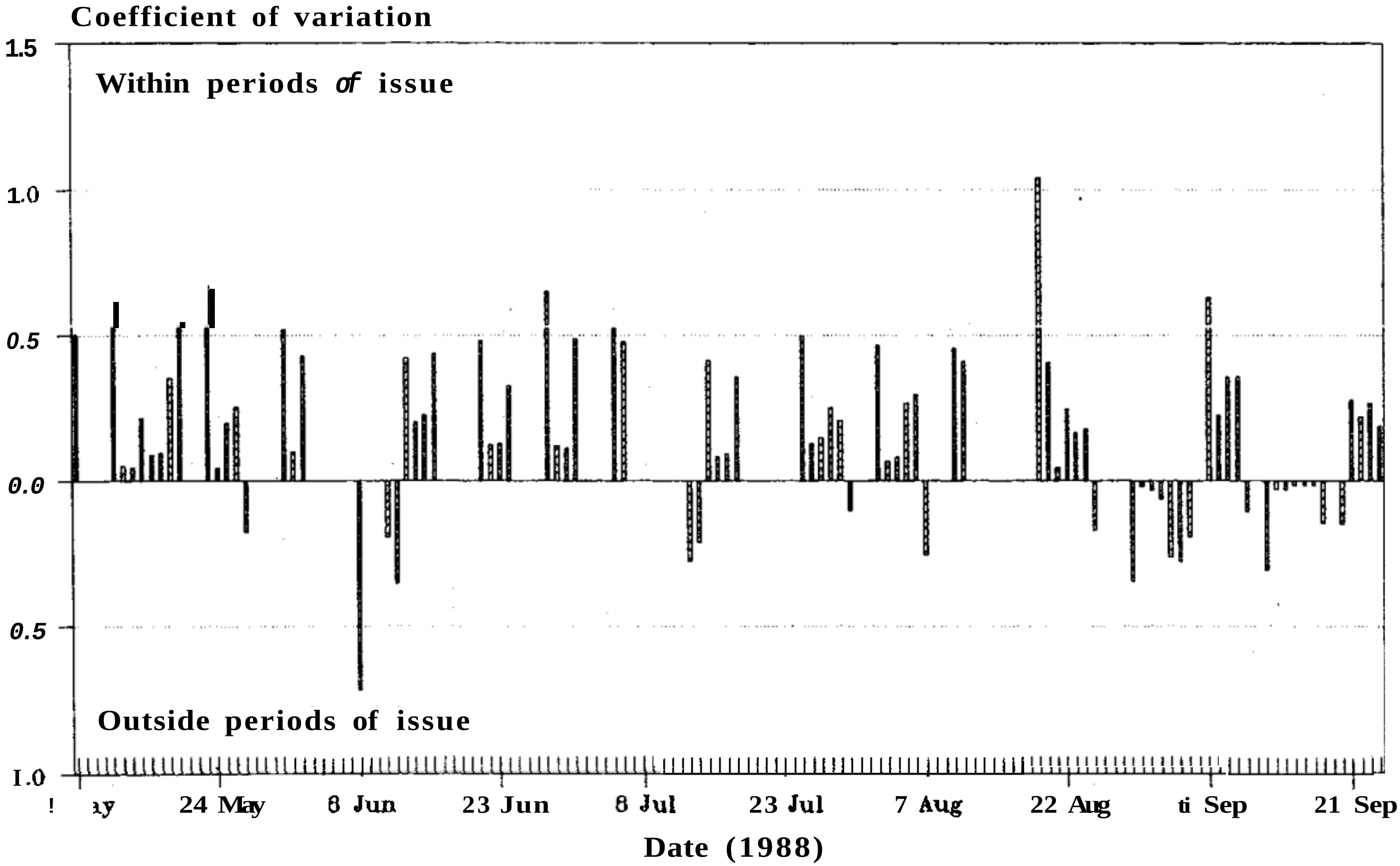
Figure V.5 Kalankuttiya: Daily coefficient of variation of water level in the branch canal (near DBW1)



Water level in the branch canal is measured above the pipe invert level of offtake 305 D3

Figure V.6

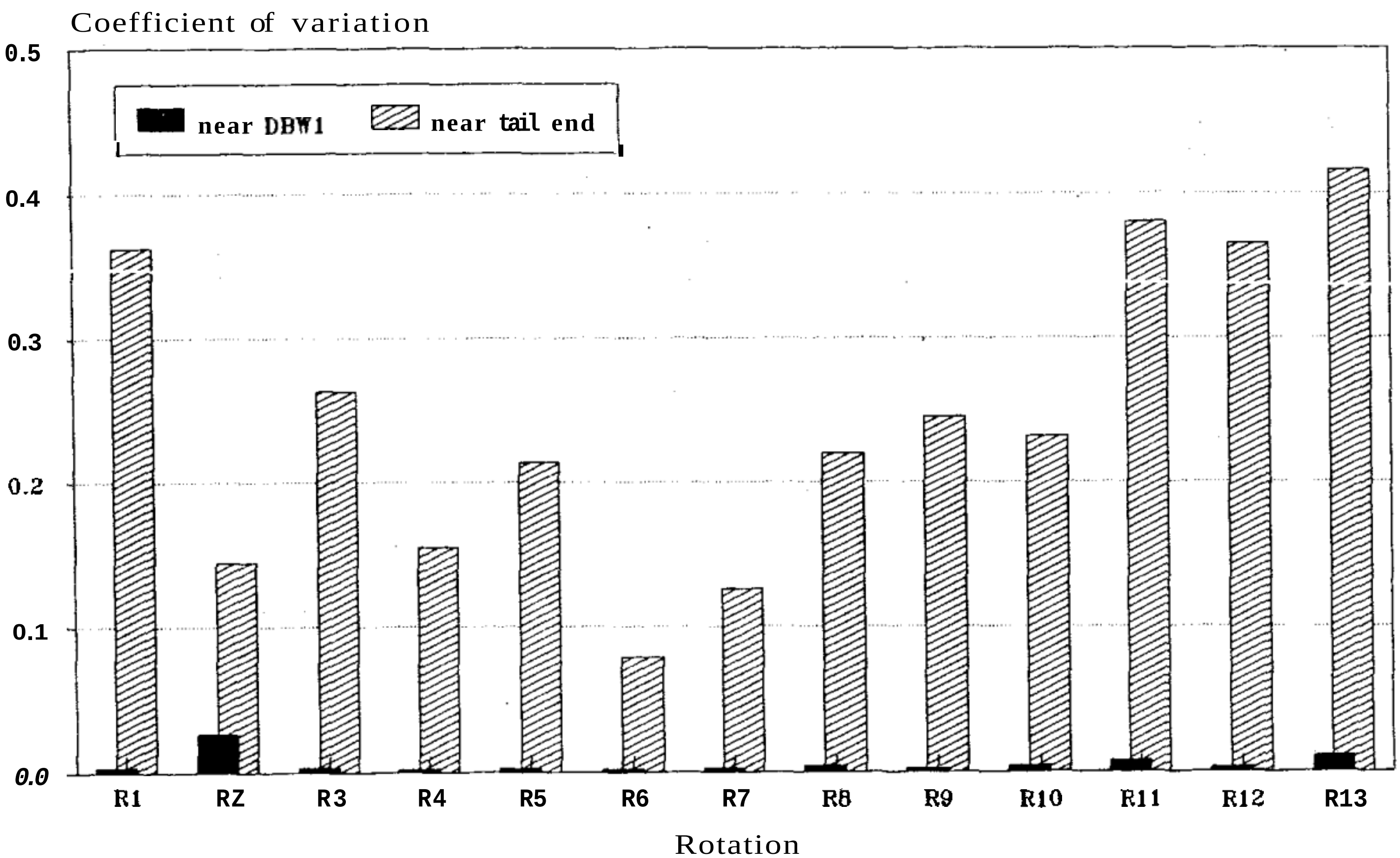
Kalankuttiya: Daily coefficient of variation of water level in the branch canal at the tail end



Water level in the main canal is measured above the pipe invert level of offtake 307 D3

CV has not been computed when there is no flow over the whole day in the branch canal at the tail end

Figure V.7 Kalankuttiya: Coefficient of variation of water level in the branch canal during each rotation



Water level in the branch canal is measured above the pipe invert level of 305-D3 and 307-D3 at the head and tail respectively

Figure V.8 Kalankuttiya: Coefficient of variation of discharge in distributaries 305 D3 and 307 D3 during each rotation

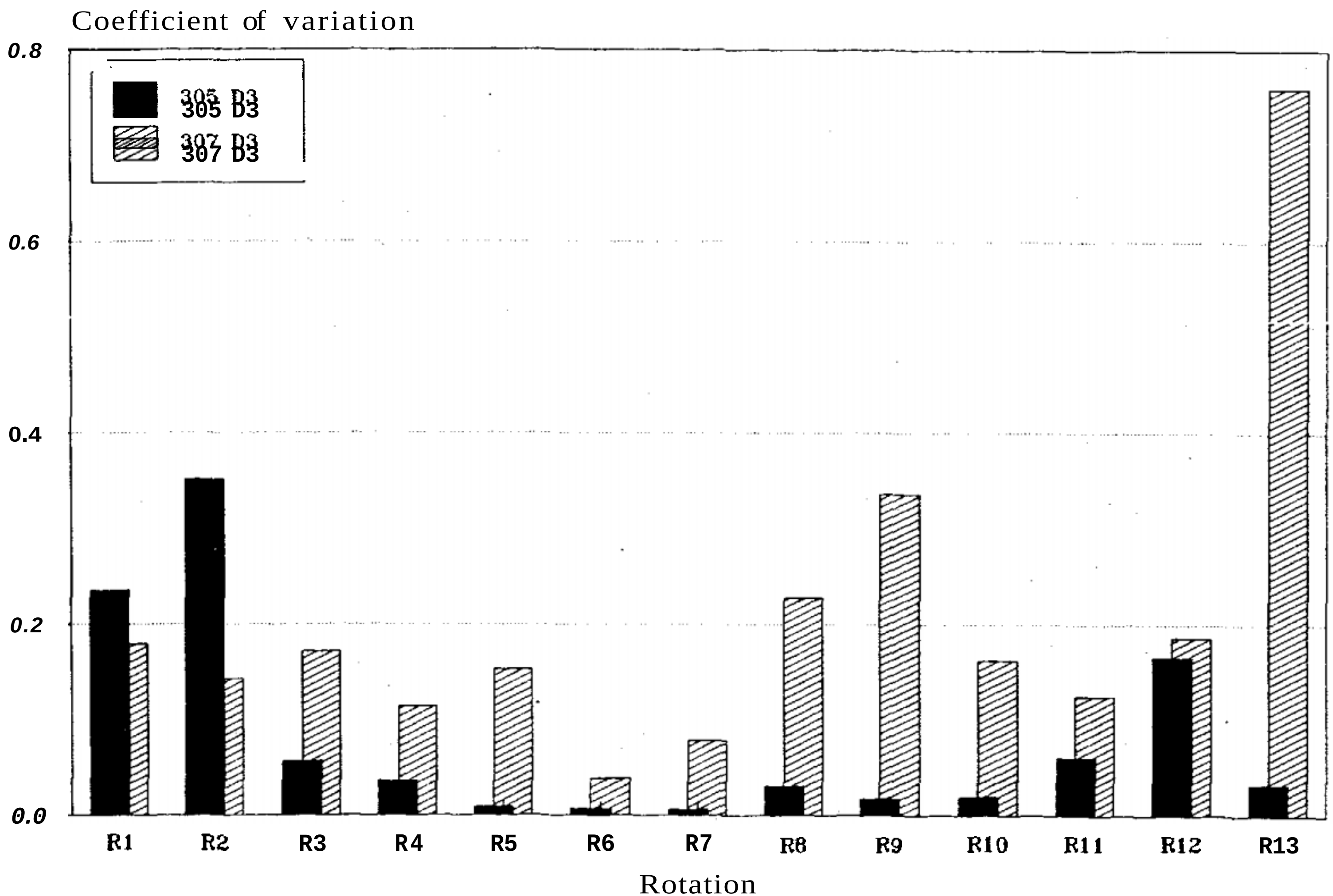


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Figure V.9 Kalankuttiya: Impact of water level variations in branch canal on variation of discharge into distributary canal 307D3

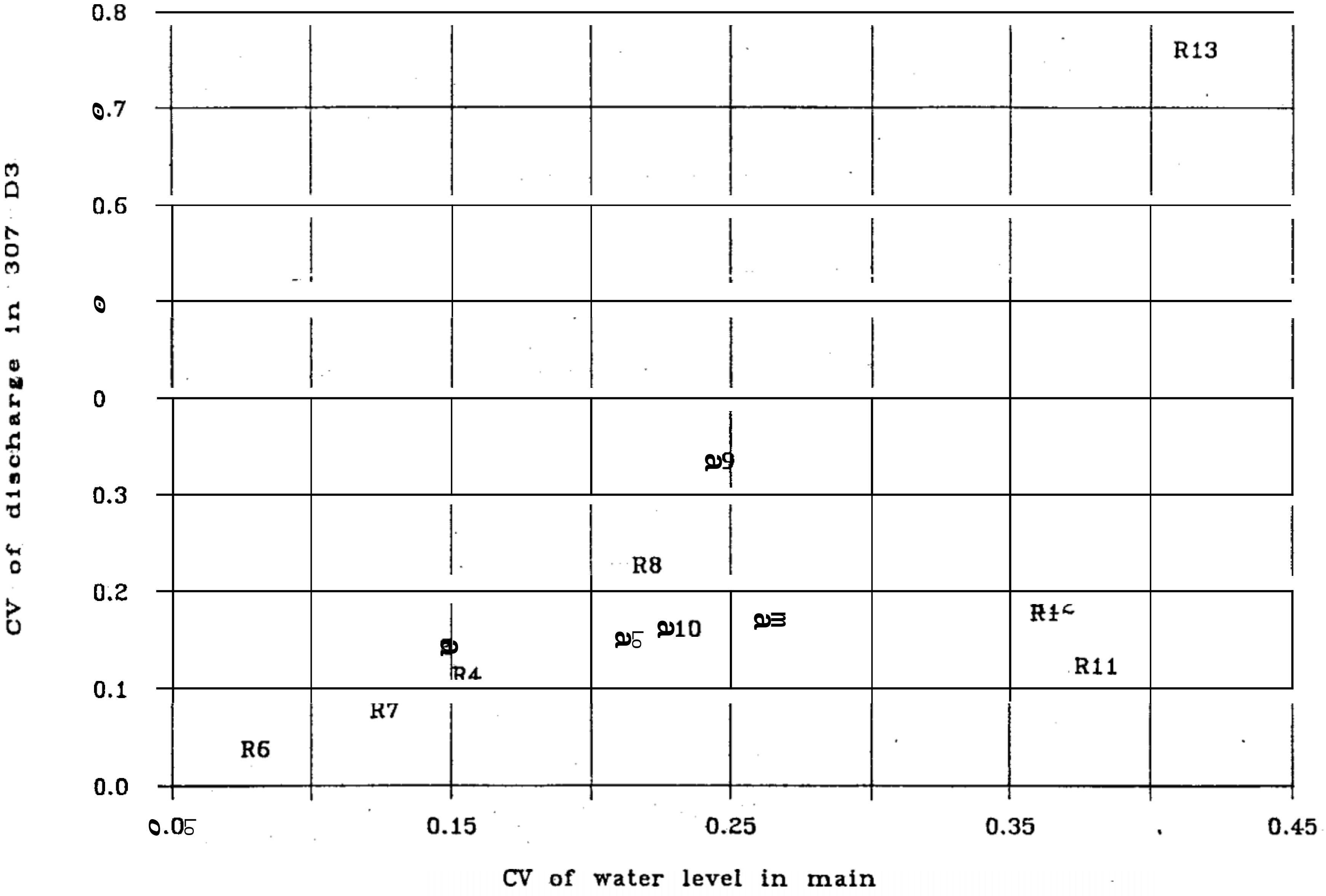


Figure V.10 Kalankuttiya: Impact of water level variations in branch canal on variation of discharge into distributary canal 305D3

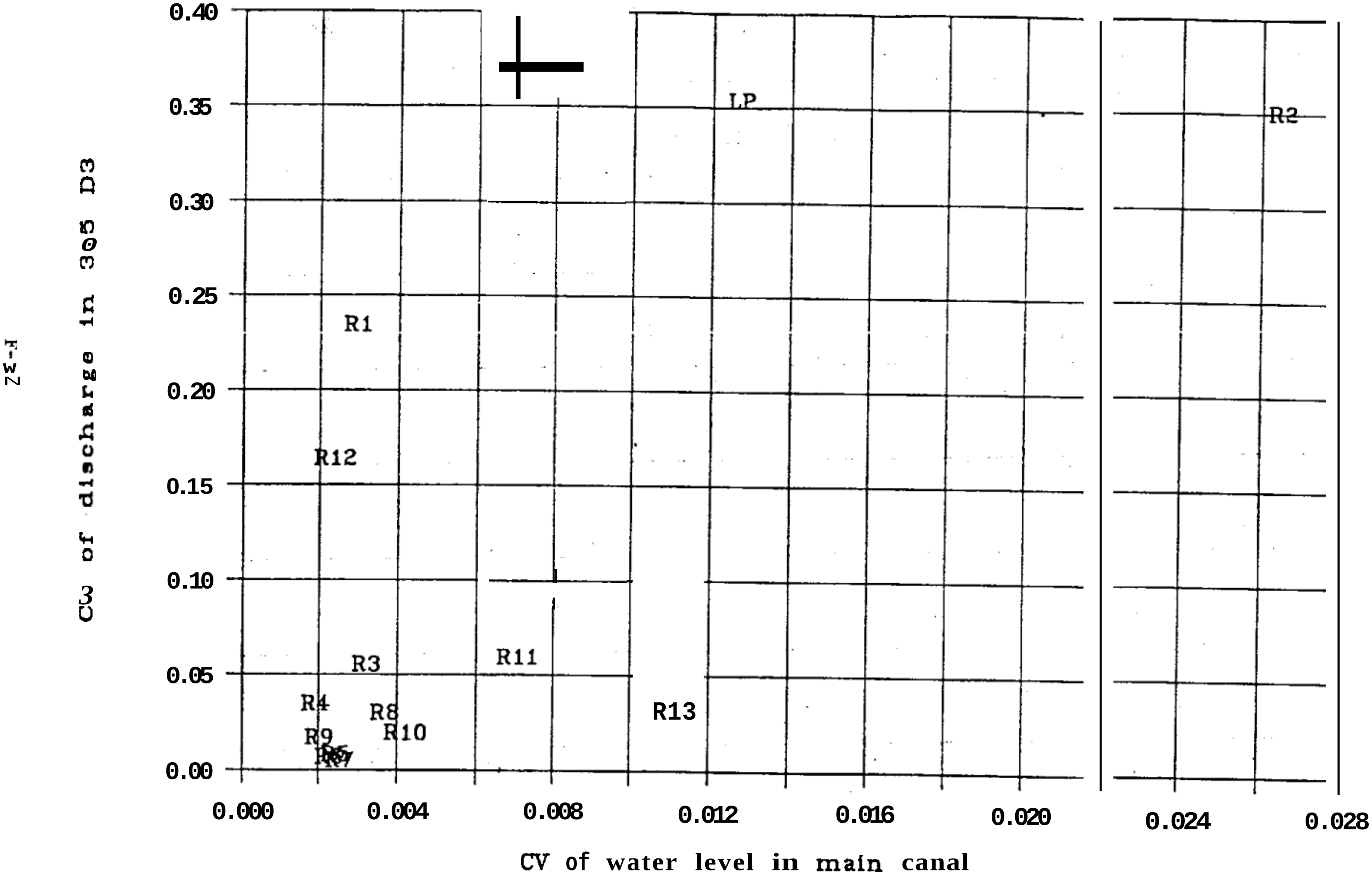


Figure V. 11 Kirindi Oya: Daily range of water level variation in the main canal near DC5 06 March to 29 June 1988

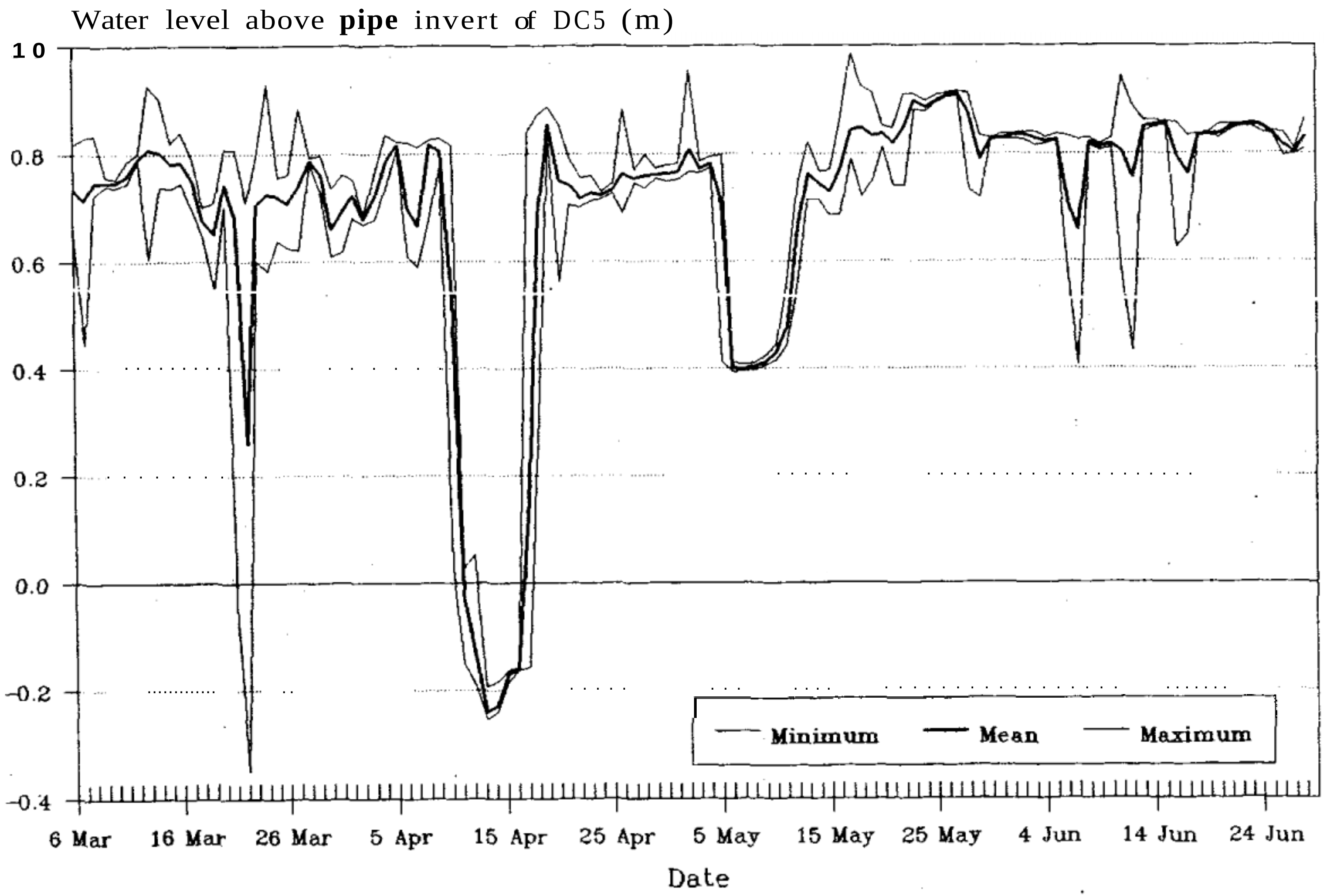


Figure V.12 Kirindi Oya: Daily range of water level variation in the main canal near BC2 06 March to 29 June 1988

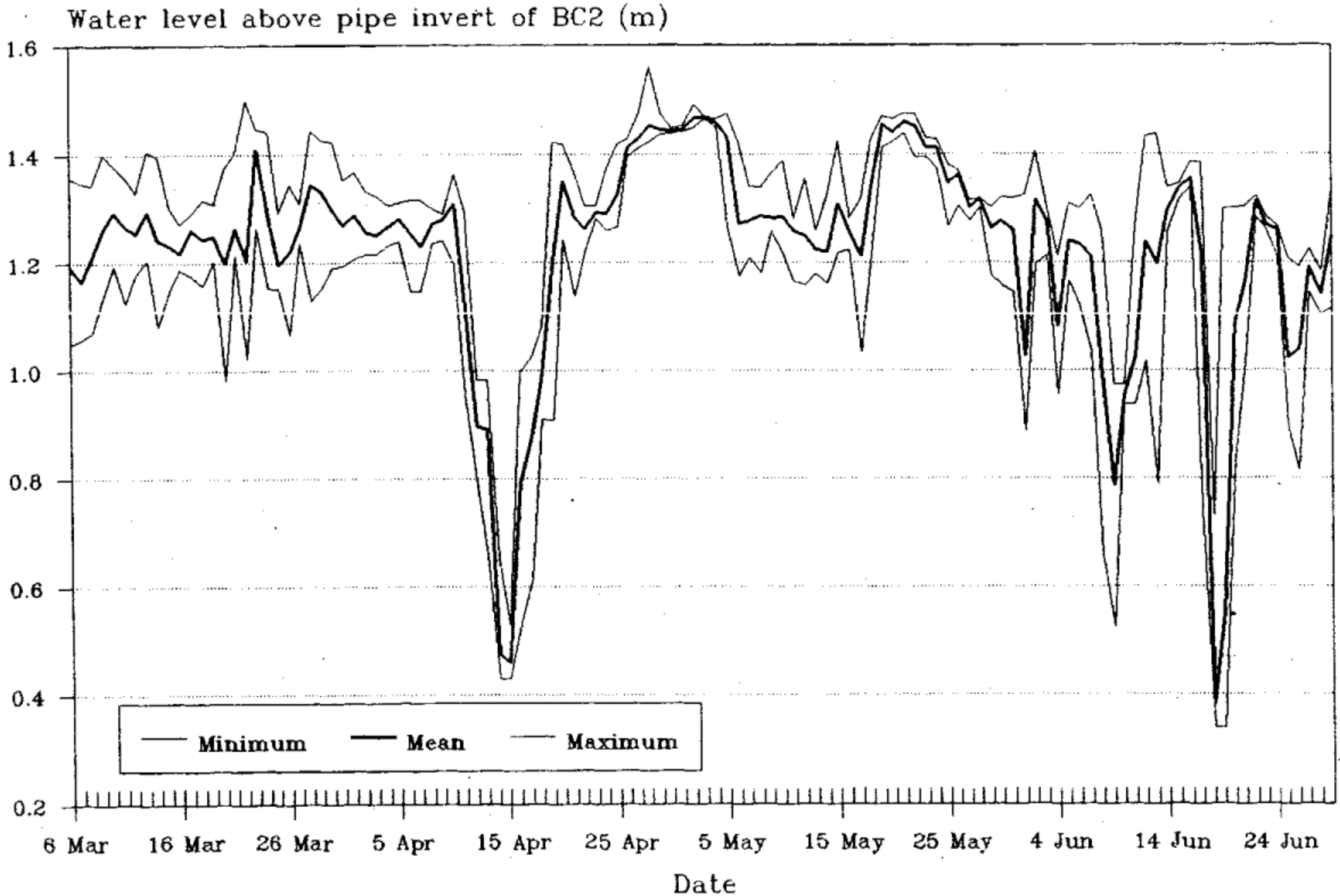
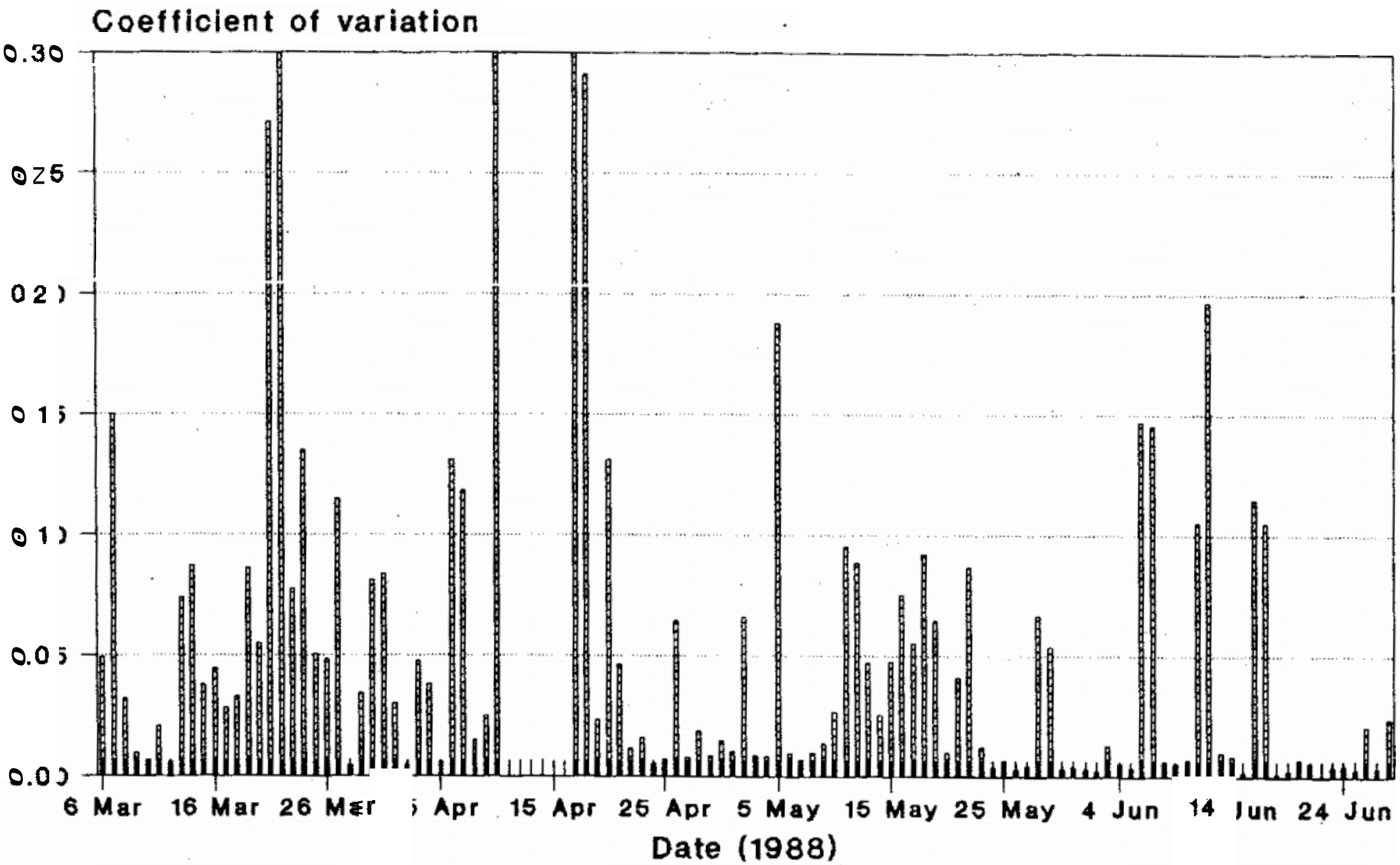


Figure V.13 Kirindi Oya: Daily coefficient of variation of water level in the main canal near distributary canal DC5



Water level in the main canal is measured above the pipe invert level of distributary canal DC5

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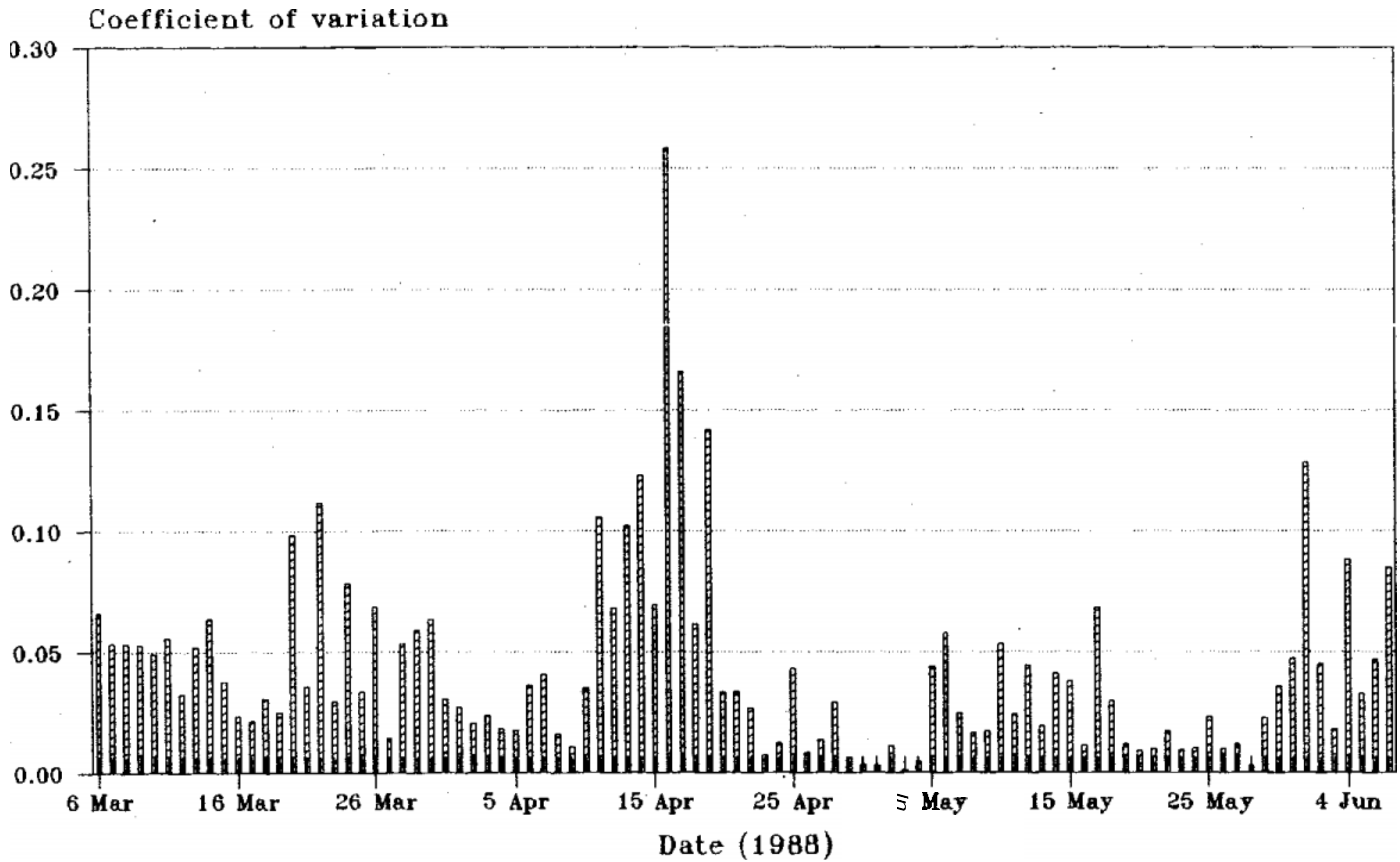
Figure V.14 Kirindi Oya: Daily coefficient of variation of water level in the main canal near branch canal BC2



Water level in the main canal is measured above the pipe invert level of branch canal BC2

Table V.15

Kirindi Oya RBMC

Water levels near DC5 and BC2, 16 - 24 April 1988

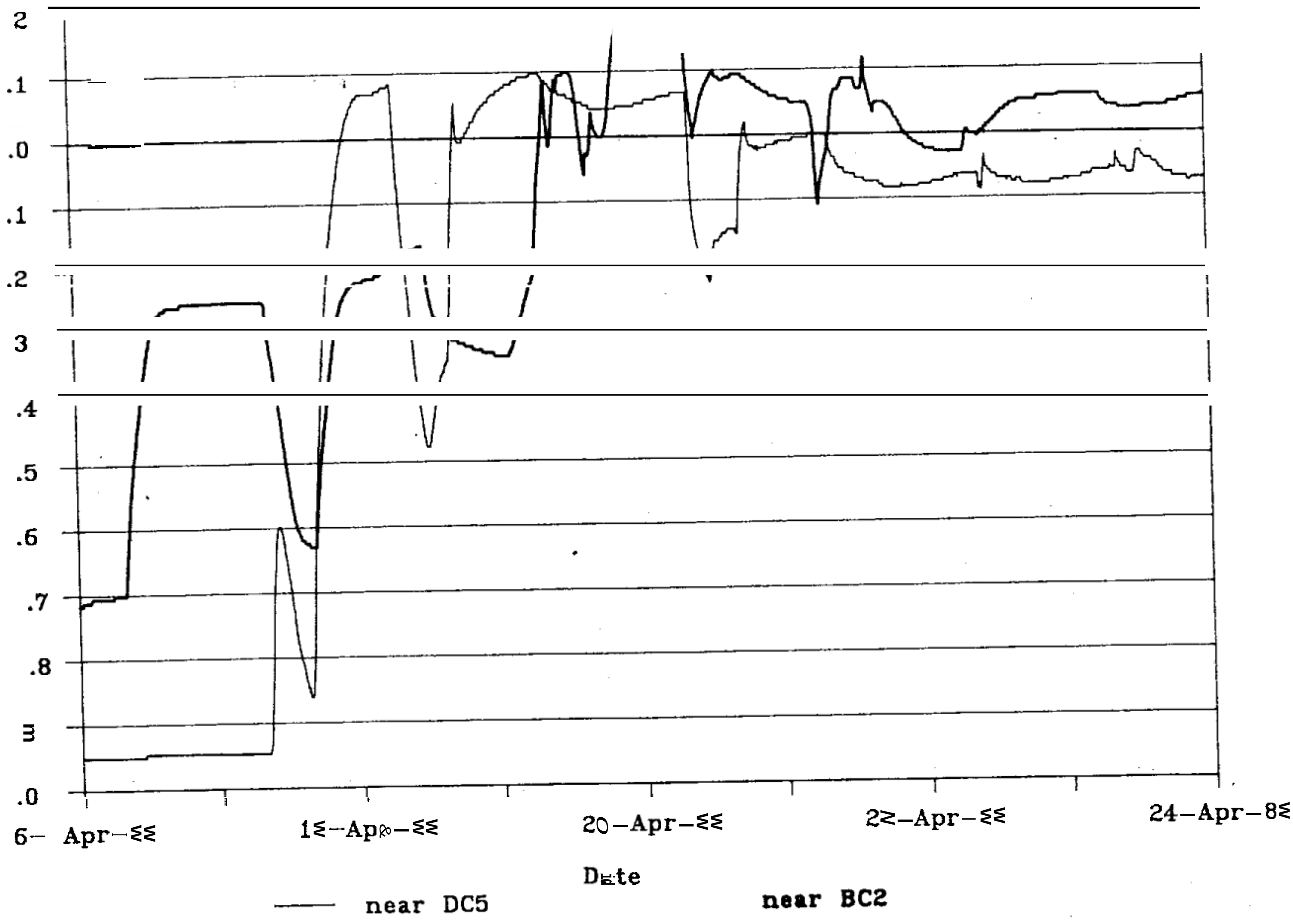
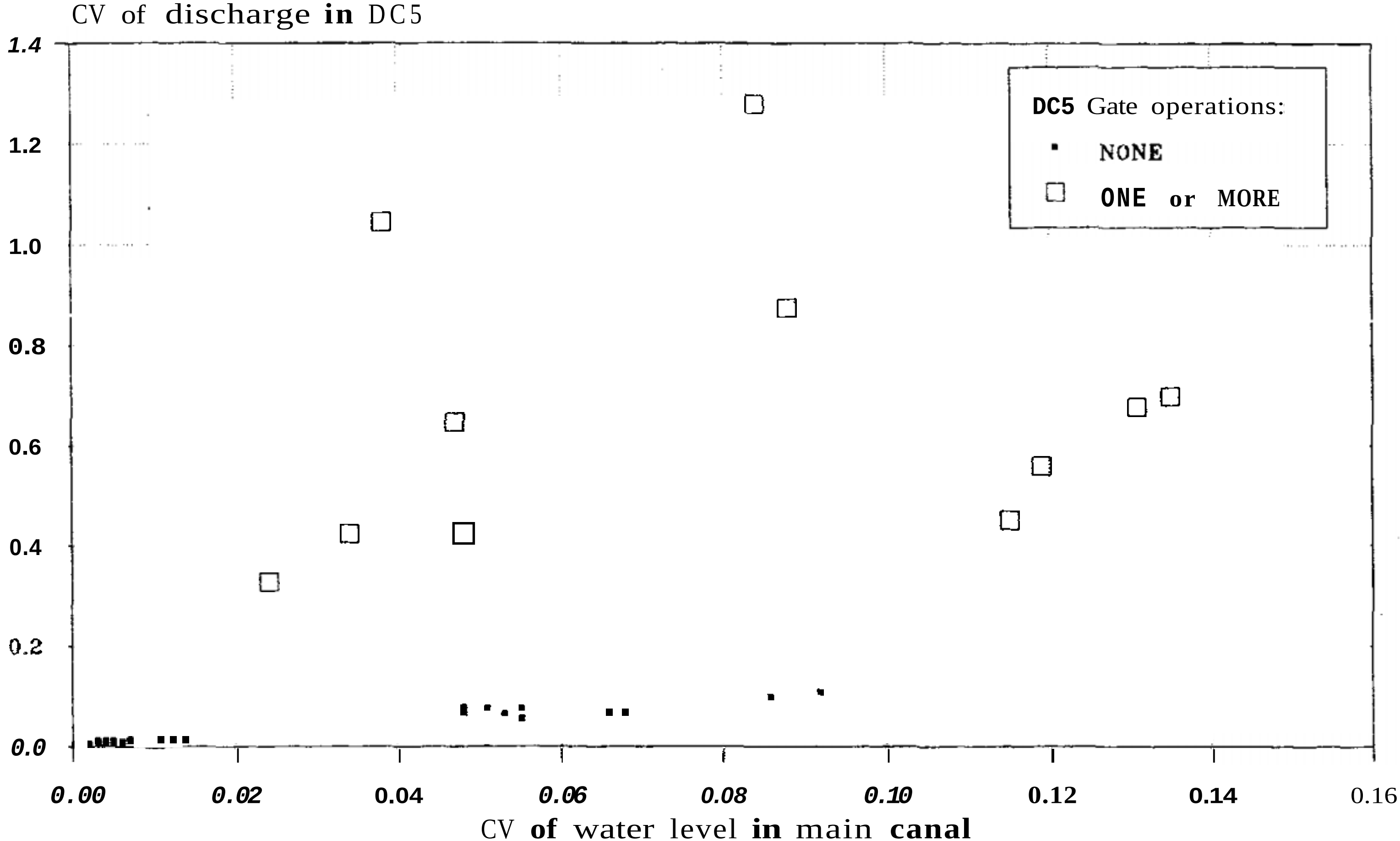


Figure V.16 Kirindi Oya: Comparison of daily coefficient of variation of water level in main canal and coefficient of variation of discharge in DC5



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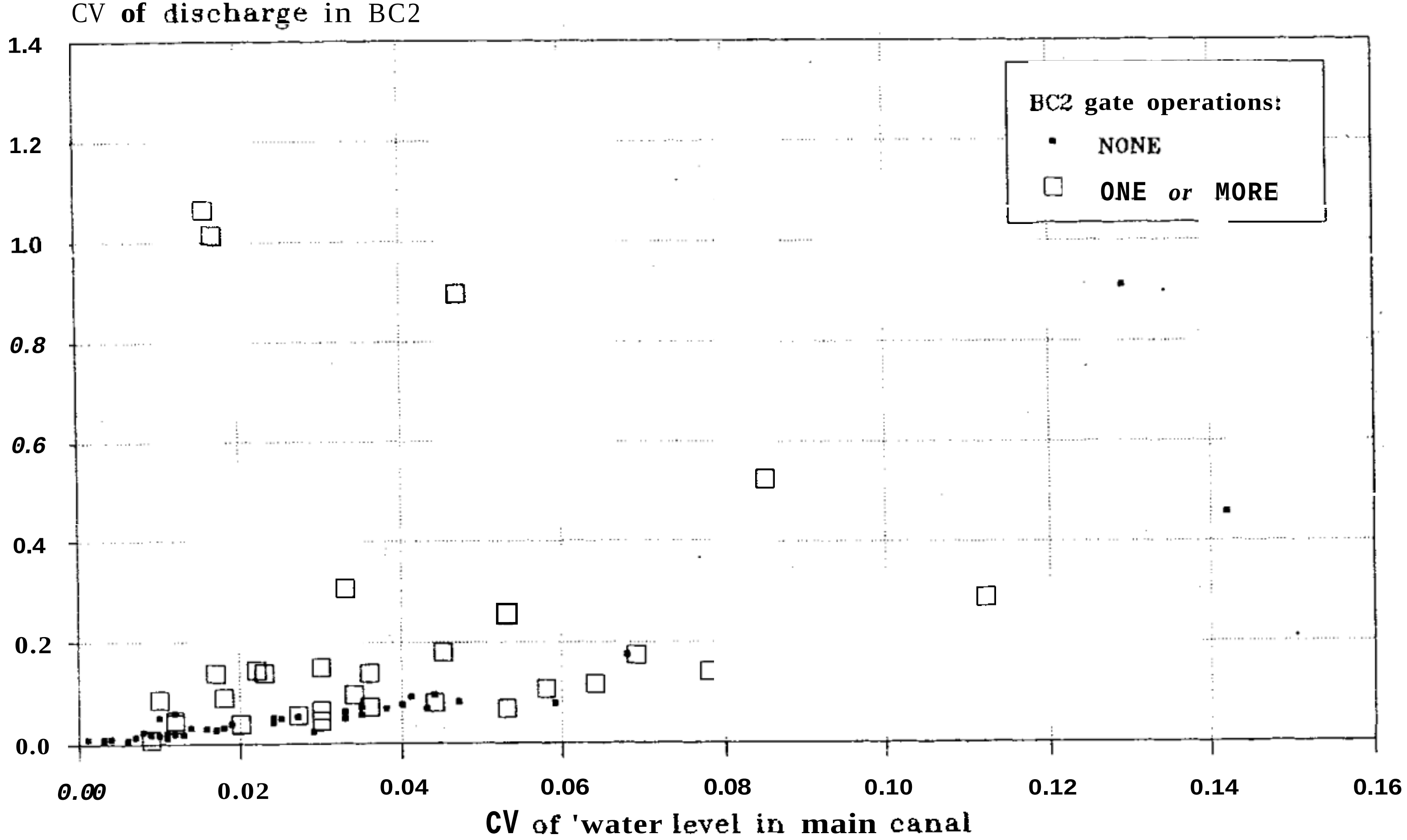
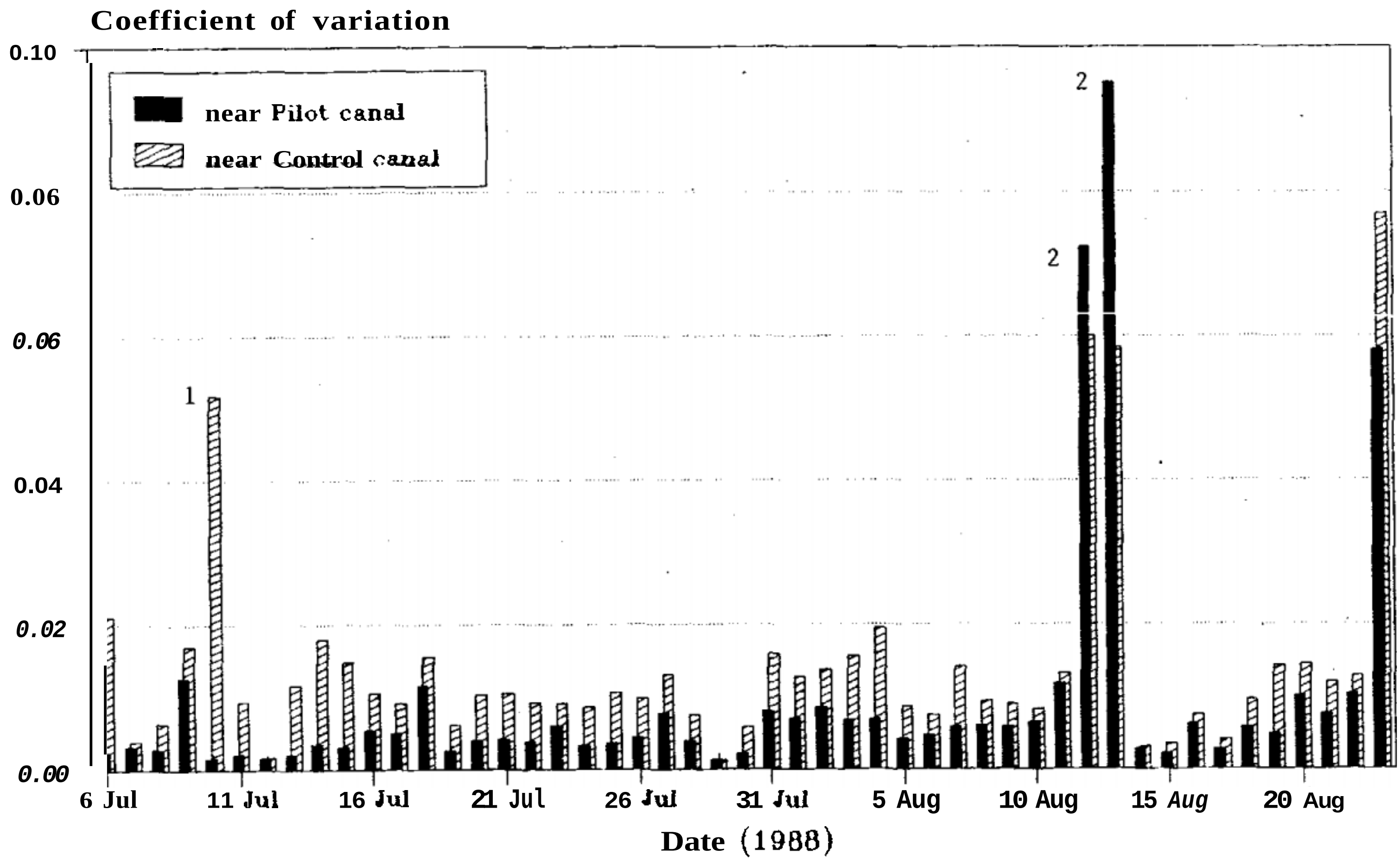
Within the set of points where there are no **gate** operations in DC5, the area of gate opening is **also** approximately equal

Figure V.17 Kirindi Oya: Comparison of daily coefficient of variation of water level in main canal and coefficient of variation of discharge in BC2



Within the set of points where there are no gate operations in BC2, the area of gate opening may differ from day to day

Figure V.1 Rajangana: Daily coefficient of variation of water level in the left hank main canal

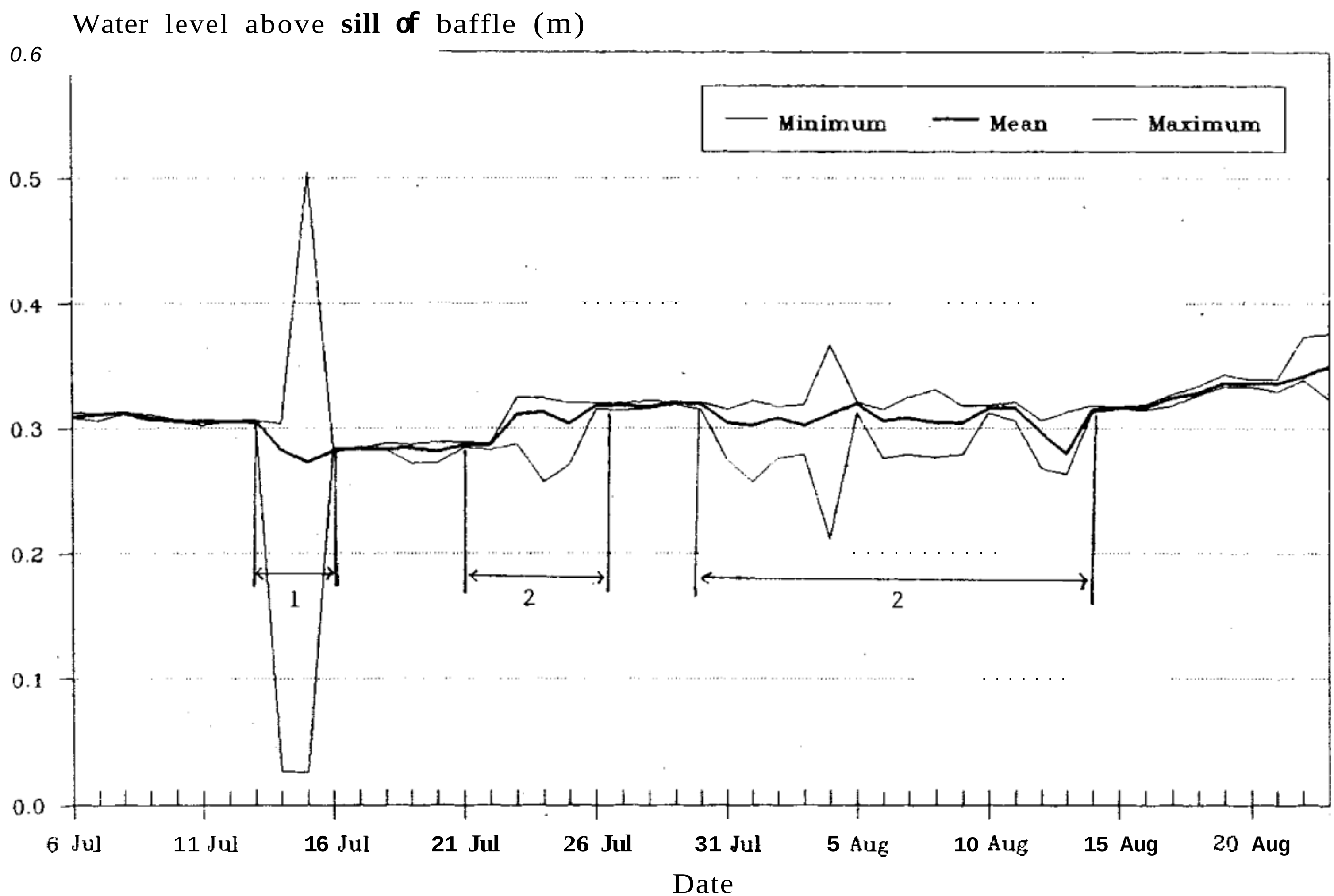


Water level is measured above the respective pipe invert Levels of the distributary canals

1 Effect of fluctuation in main canal discharge

2 Effect of fluctuation in main canal discharge (discussed in Annex IV.1)

Figure V.19 Rajangana: Daily range of water level variation in the pilot distributary canal upstream of the baffle distributor



1 Baffle distributor under repairs 2 Night interventions on baffle distributors

Figure V 20 Rajangana: Daily range of water level variation in the main canal near the control distributary canal

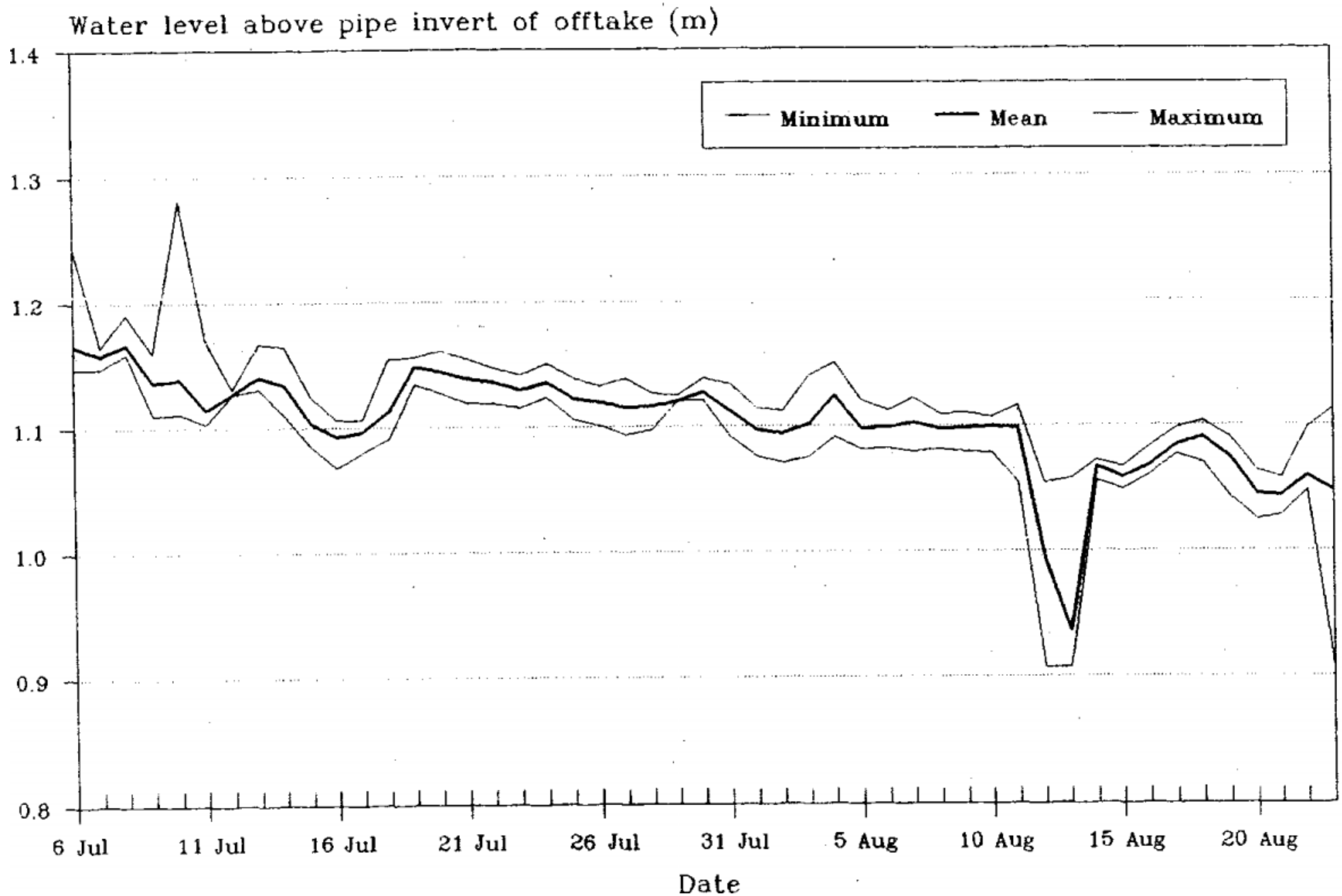
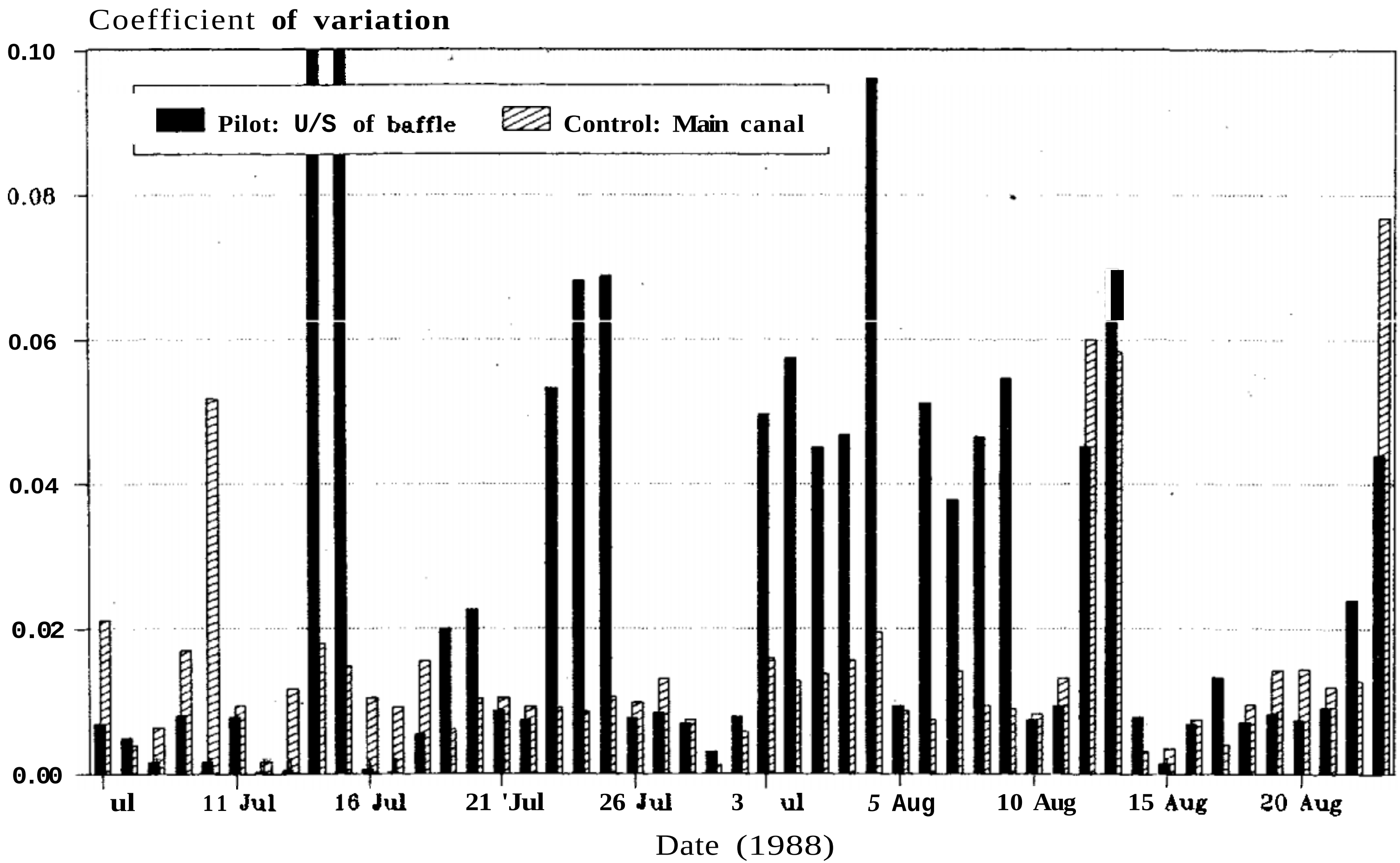
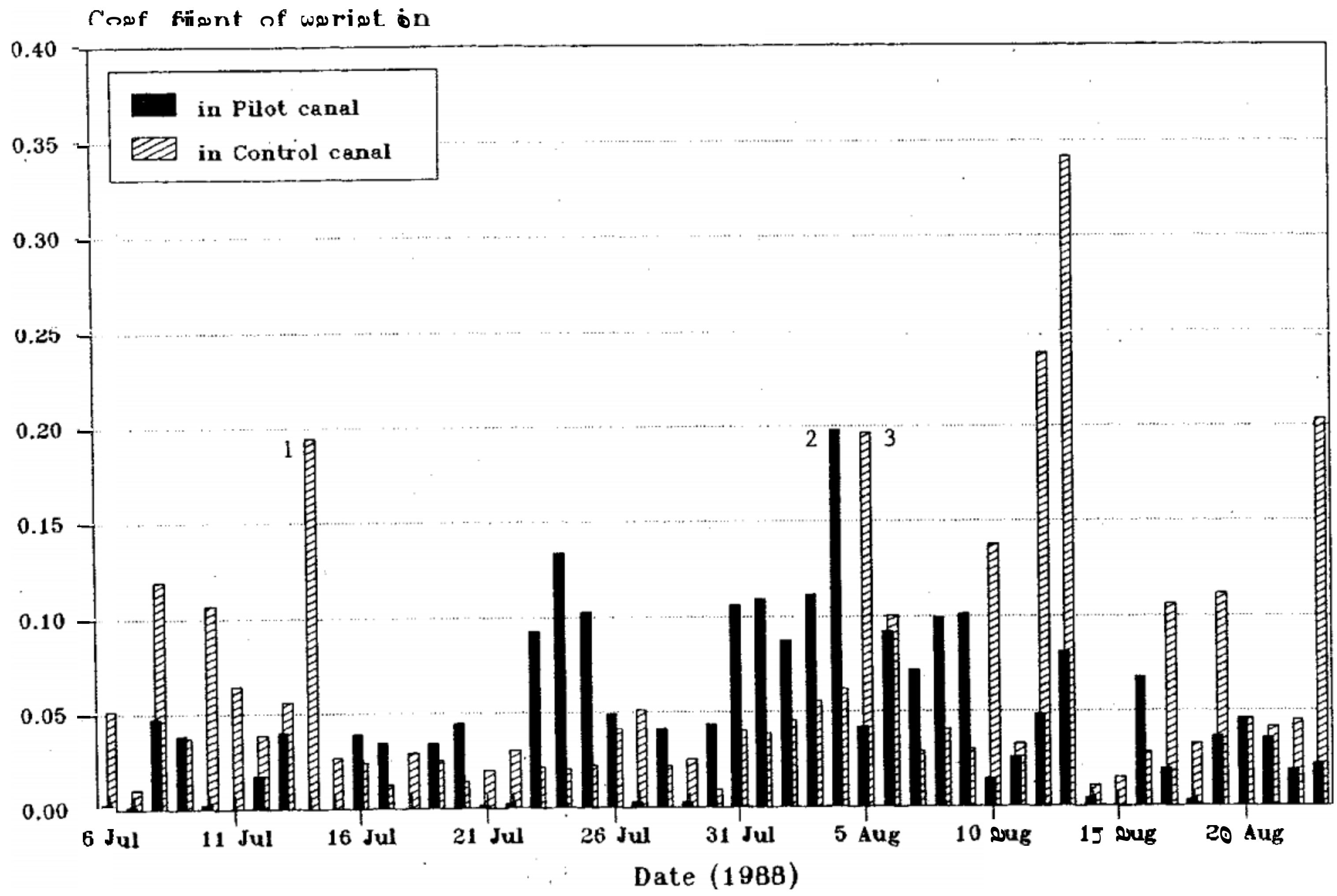


Figure V.21 Rajangana: Daily coefficient of variation of water level in main canal near control distributary canal and in pilot distributary canal



Water level is measured above sill of baffle distrihutor and above pipe invert of control canal respectively

Figure V.22 Rajangana: Daily coefficient of variation of discharge in pilot and control distributary canals



1 Sudden opening of Control canal gate

2 IIMI gauging in Pilot canal

3 IIM.I gauging in Control canal

Figure V.23 SDA: Daily coefficients of variation of water level in the main canal at the headgate and near laterals B and G

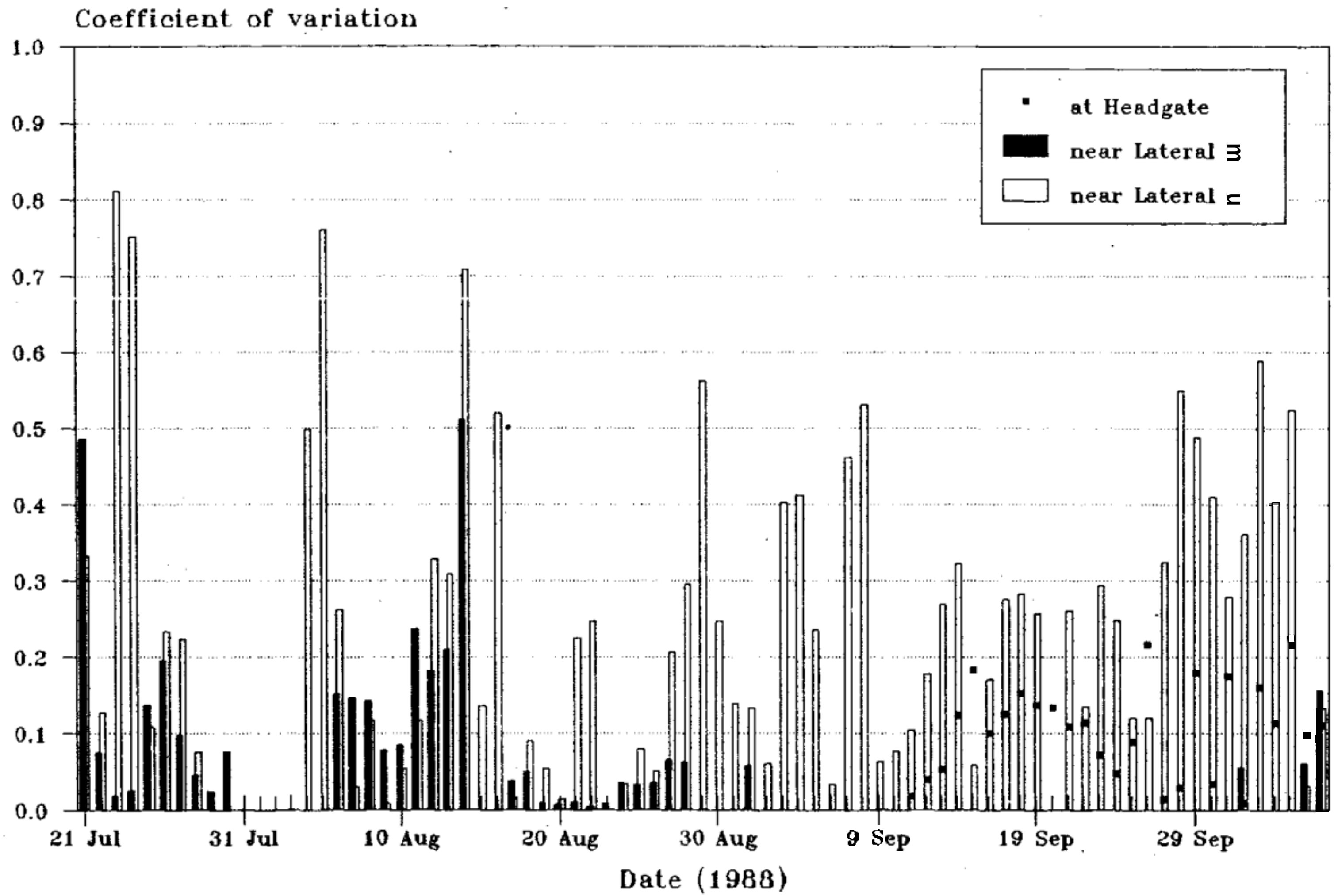


Figure V.24 SDA: Daily coefficients of variation of discharge in the main canal (at the headgate) and into laterals B and G

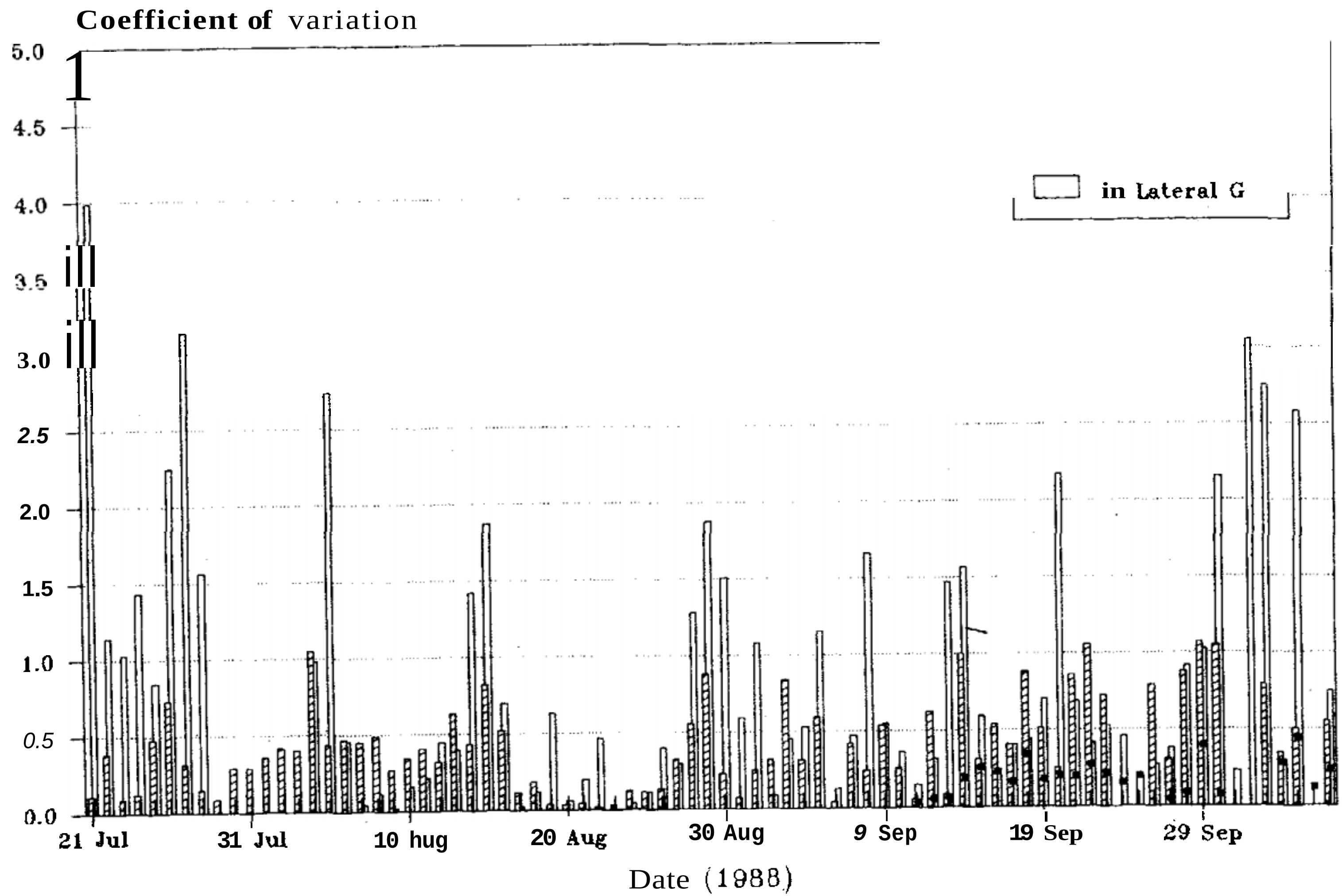


Figure V.25 SDA: Comparison of daily coefficients of variation of water level in the main canal and discharge in Lateral B

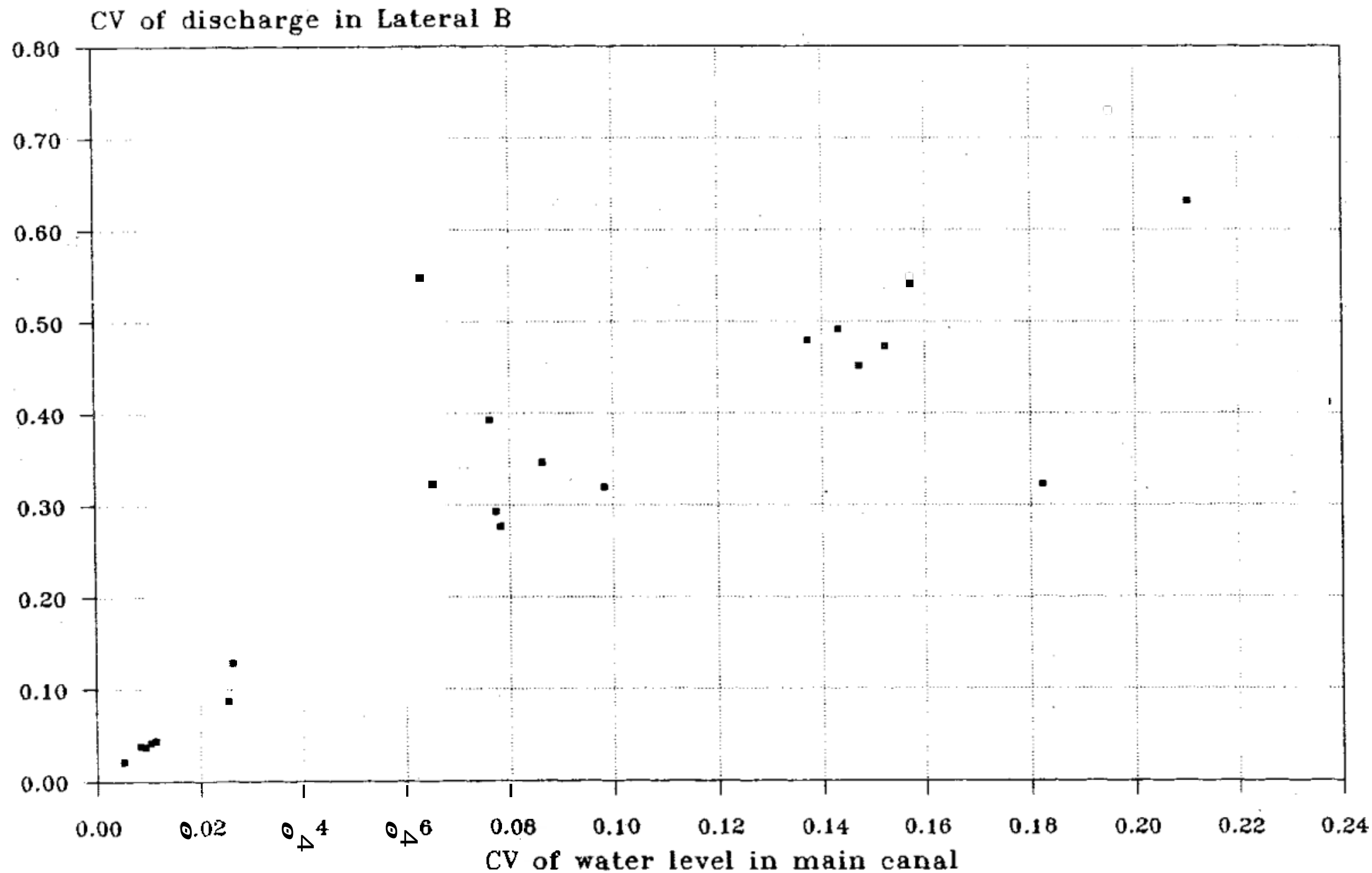


Figure V.26 Kalankuttiya Branch Canal, Yala 1988
Comparison of rotational deliveries at three locations

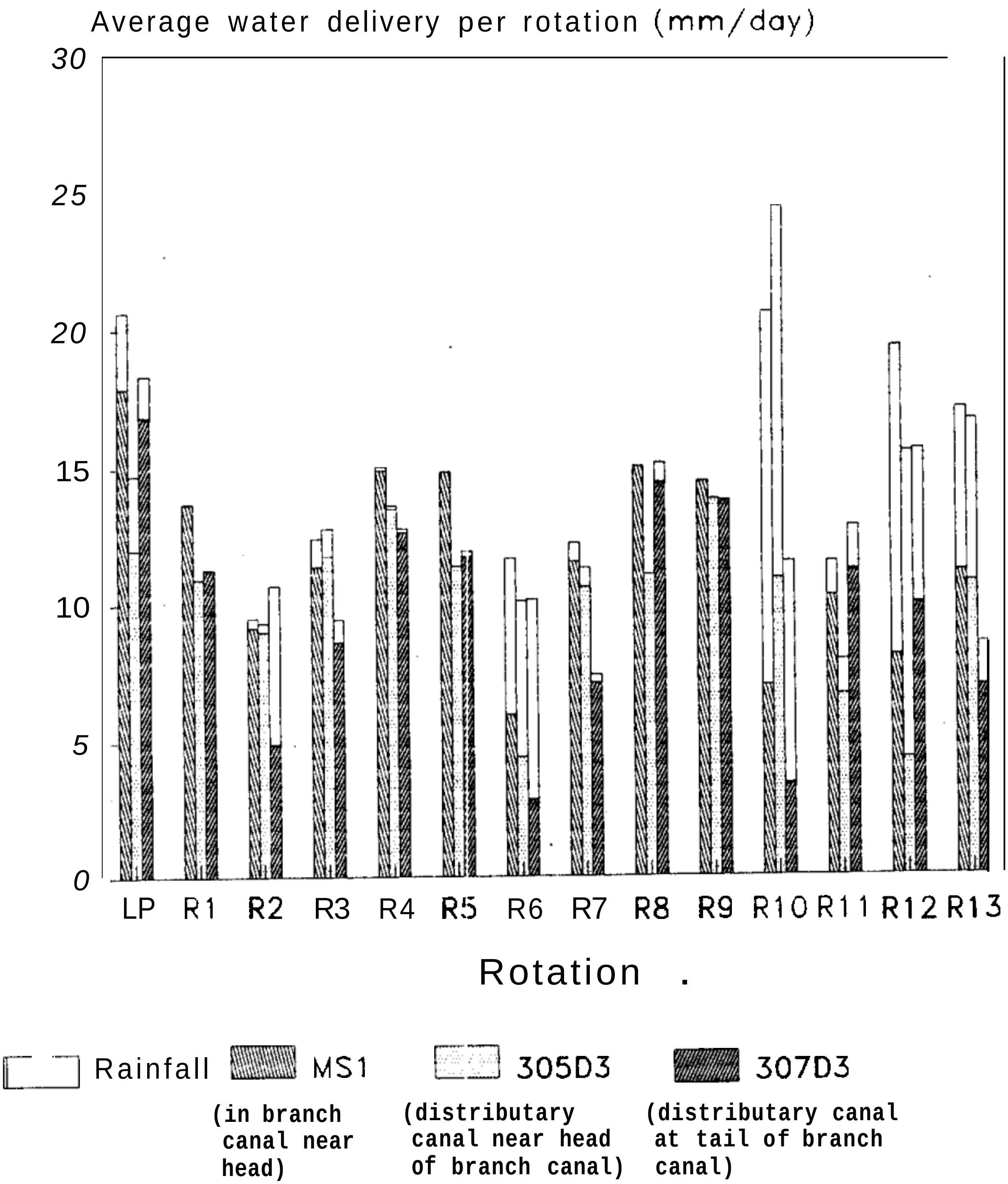


Figure V.27 Kalankuttiya Branch Canal, Yala 1988

Comparison of rotational deliveries at three locations

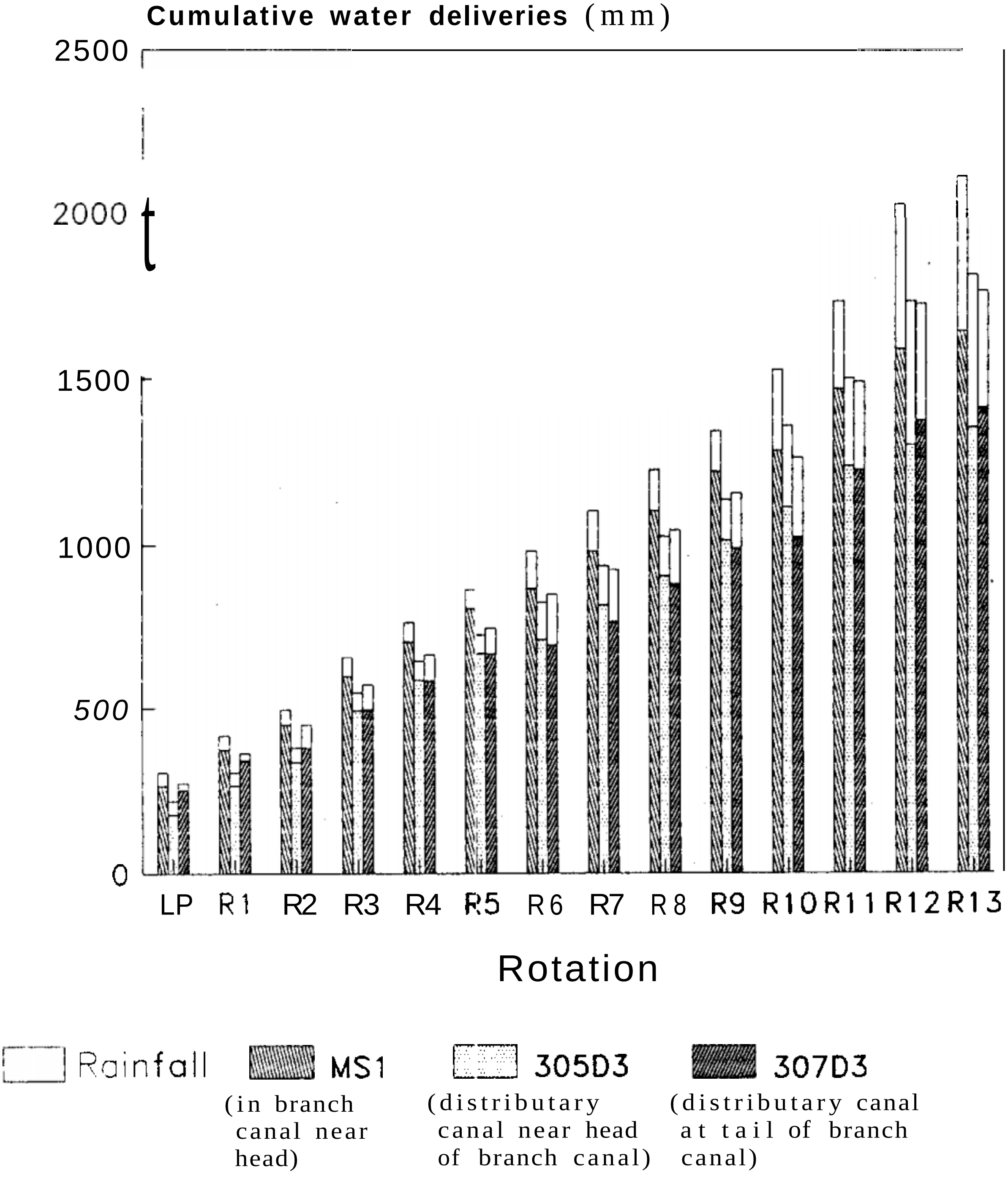


Figure V 28 Kalankuttiya: spatial variation of daily rainfall between head and tail of system

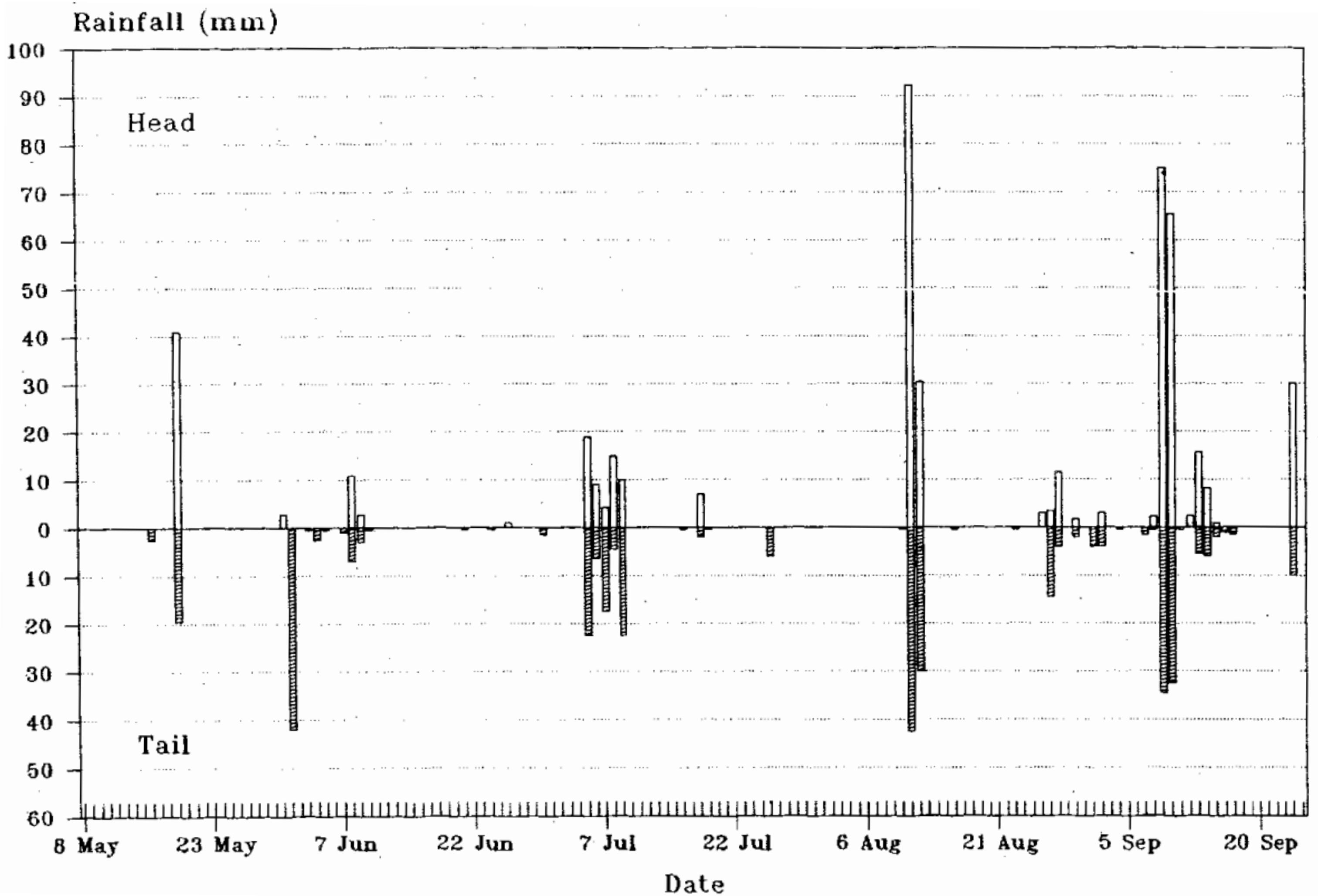
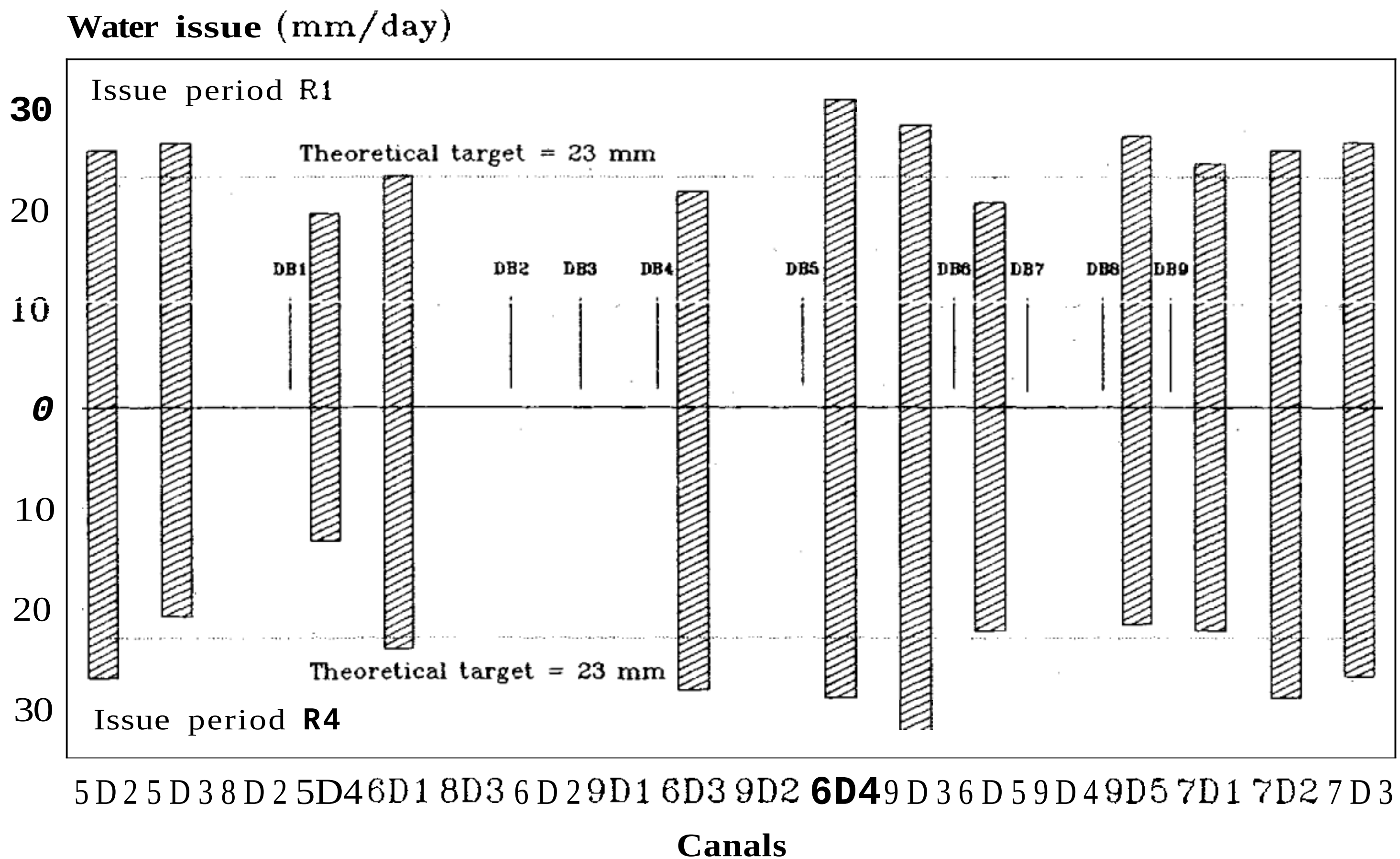


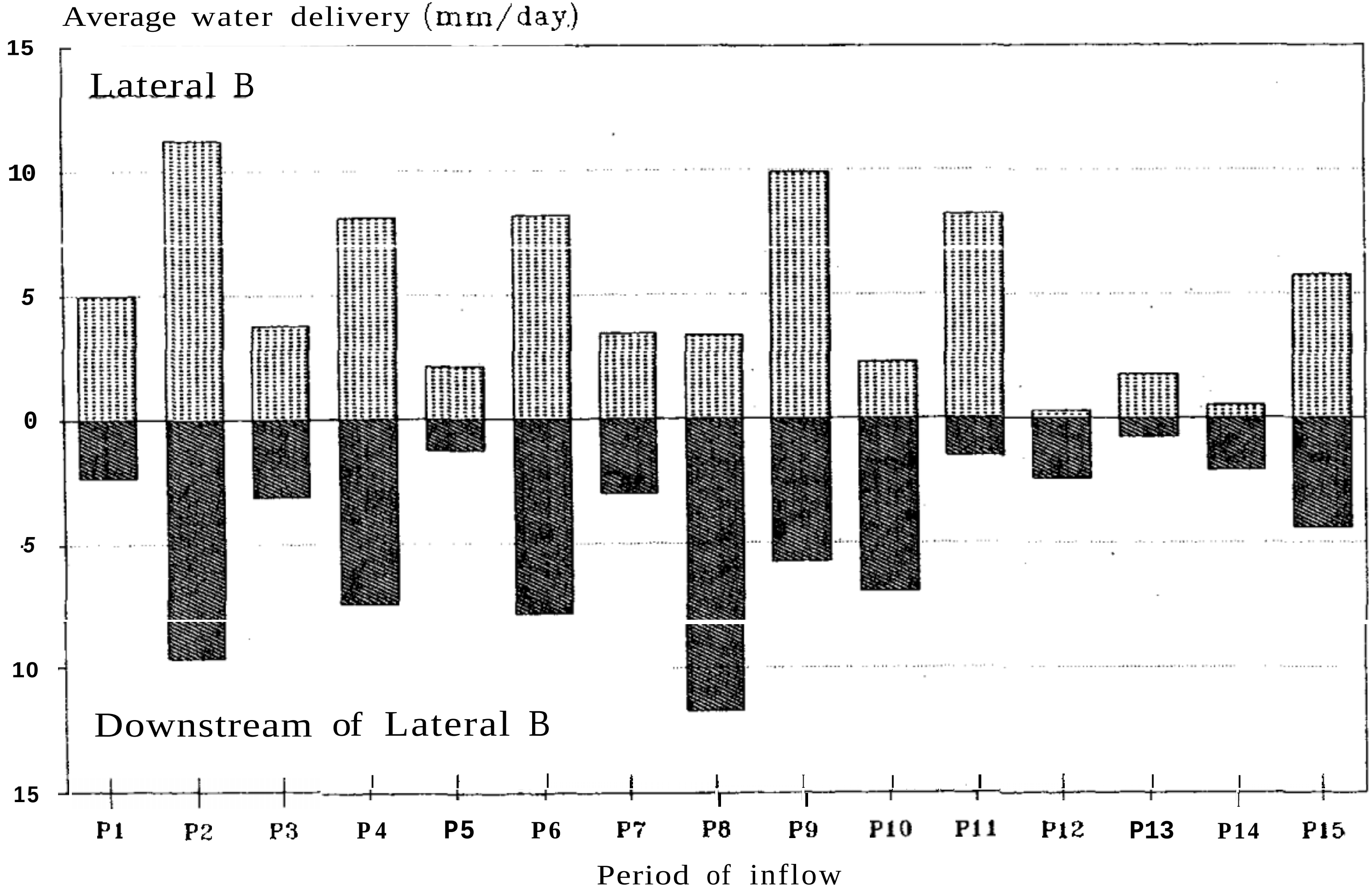
Figure V.29 Kalankutiya BC: Water deliveries to individual distributary canals during rotations R1 & R4, Yala 1988



DB : DuckBill weir
Target/wk = 64 mm/wk+10% DC & FCs losses
Target/day= (Target/wk) / 3 day duration

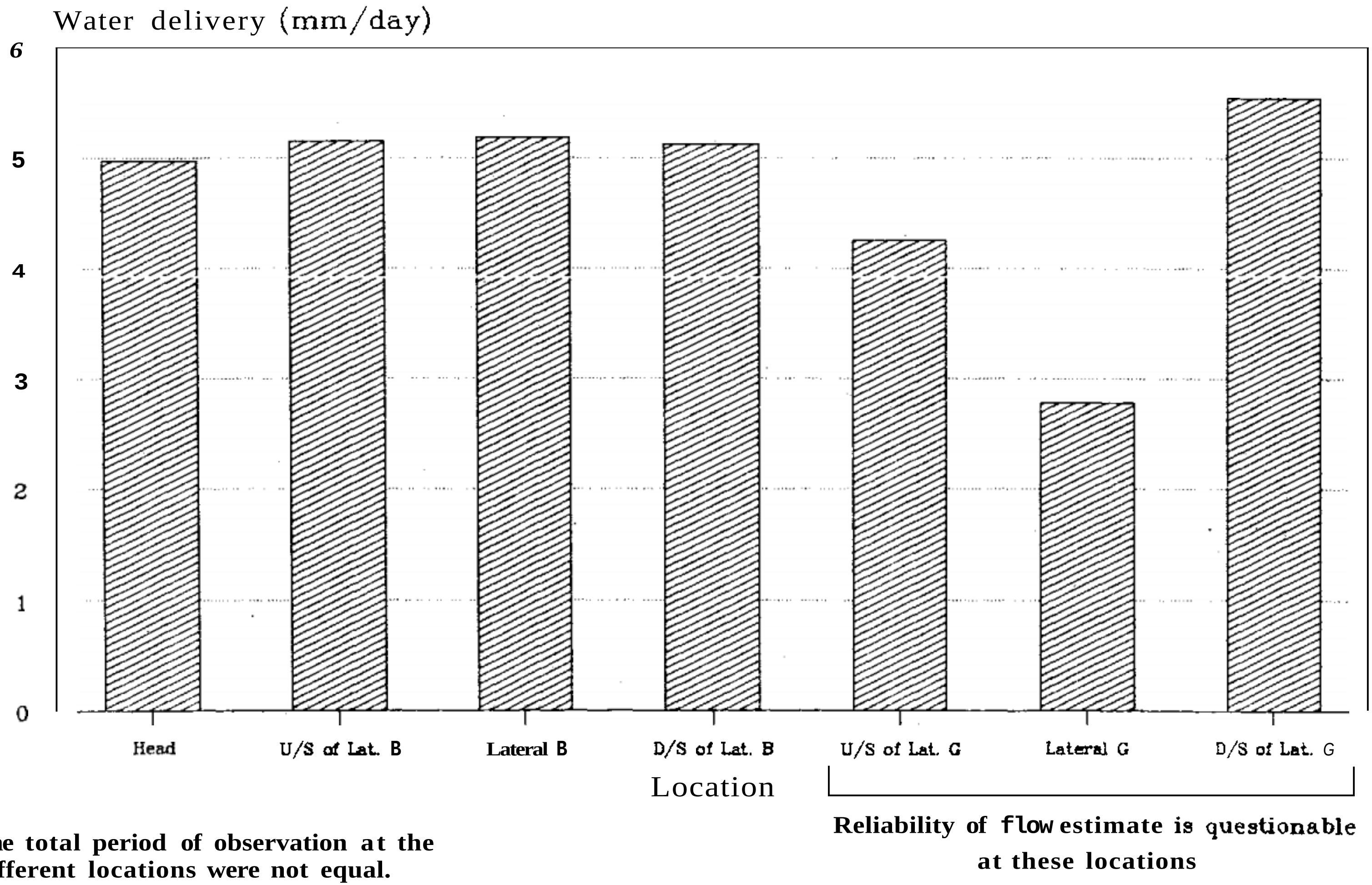
[-11]

Figure V.30 SDA, sharing of water deliveries at Lateral B for different periods of inflow, 21 July to 07 October 1988



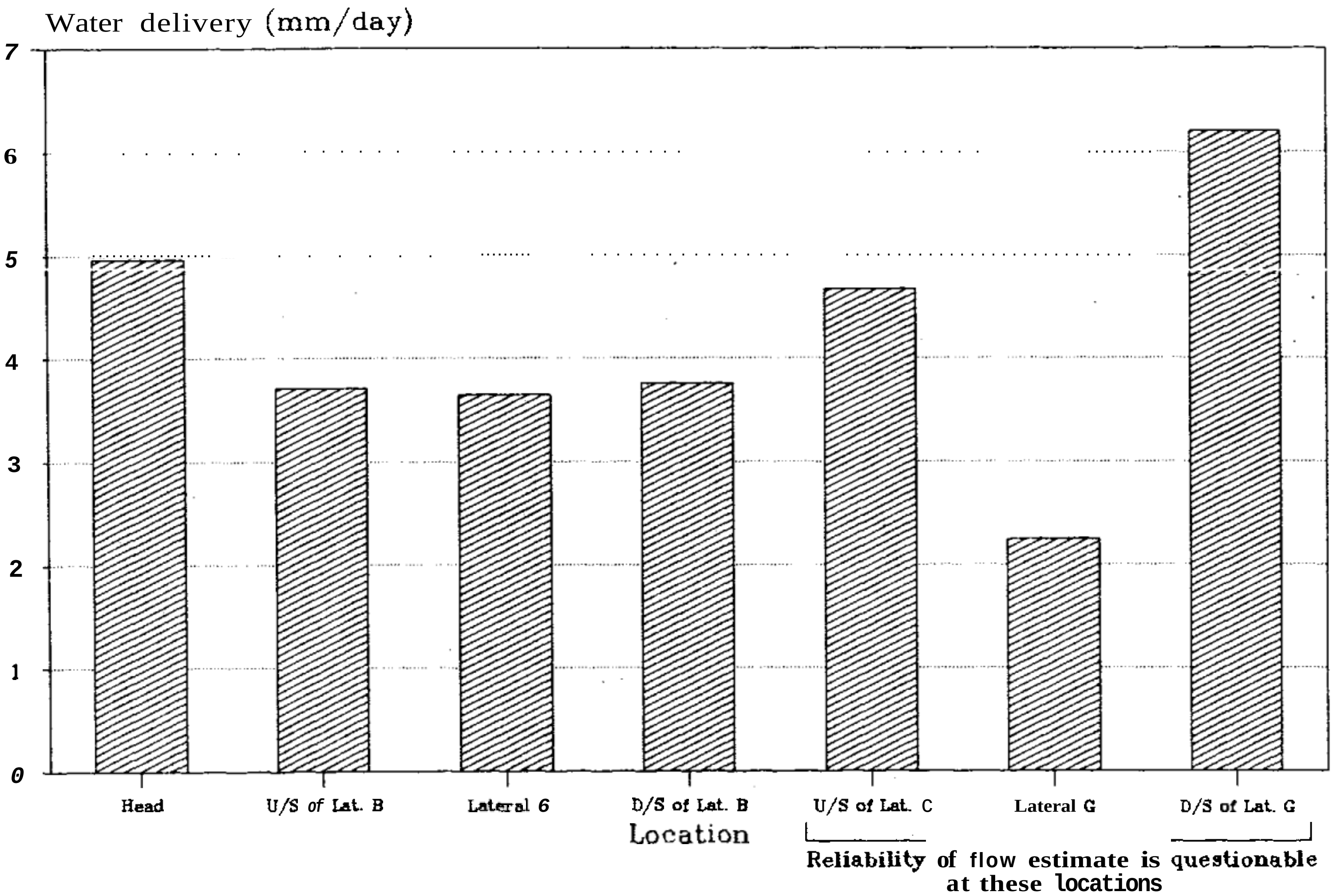
F-11z

Figure V.31 SDA, Comparison of average seasonal water delivery at different locations 21 July to 07 October 1988



The total period of observation at the different locations were not equal. Refer table for actual periods.

Figure V.32 SDA, Comparison of average water delivery at different locations 12 September to 07 October 1988



Tables

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Table 1.2. List and location of the recording stations used for the study.

Kalankuttiya: (record from 01/01/88 to March 88 and from May up to 30/09/88)

- 1 single stage mechanical recorder located 200 meters downstream of the head of the Branch Canal (MS1), operated by the MEA Flow Monitoring Unit.
- 1 automatic electronic datalogger' at the tail of the Branch Canal (BC) fitted with 3 ultrasonic sensors: 1 in the BC and at each of the 2 lateral offtnkes 307 D2 and 307 D3.
- 1 automatic electronic datalogger at the first duckbill weir fitted with 3 ultrasonic sensors: 1 upstream of the regulator and 1 each at the head of the adjacent distributary canals 305 D3 and 308 D2.

Santo Domingo Area: (record from 20/07/88 up to 22/10/88)

- 1 automatic electronic datalogger at SDA/Lateral B (one-third section) fitted with 4 ultrasonic sensors: upstream and downstream of the cross-regulator in the main canal and upstream and downstream of the Parshall Flume located at the head of the adjacent Lateral B.
- 1 automatic electronic datalogger at SDA/Lateral G (two-third section of the main) fitted with 3 ultrasonic sensors: 1 each upstream and downstream of the cross-regulator in the main canal and 1 at the head of the adjacent Lateral G.
- 1 double stage mechanical recorder located at the head of SDA upstream and downstream of the main Parshall Flume. This recorder was backed up from 11/09/88 by 1 automatic datalogger fitted with 2 ultrasonic sensors.
- 2 single stage mechanical recorders located at the middle sections of SDA and Lateral B, respectively.

Kirindi Oya: (record from 05/03/88 up to 29/06/88)

- 1 automatic electronic datalogger at the RBMC/GR3 (gated-regulator no. 3) fitted with 3 ultrasonic sensors: 1 each upstream and downstream of the cross-regulator and 1 at the offtake of the adjacent distributary canal, DC5, in tract 1.
- 1 automatic electronic datalogger at RBMC/GR12 fitted with 4 ultrasonic sensors: upstream and downstream of the cross-regulator in the main canal and upstream and downstream of the measuring weir in the adjacent branch canal, BC2, in tract 5.

Rajangana: (record from May 1988 up to 10/09/88)

- 1 automatic electronic datalogger at the head of the Pilot Area (LB tract 2, DC1) fitted with 3 ultrasonic sensors: 1 in the main canal, 1 downstream of the constant level automatic gate, and 1 downstream of the baffle distributor of the Pilot distributary canal.
- 1 automatic electronic datalogger at the head of the Control Area (LB tract 2, DC2), fitted with 3 ultrasonic sensors: 1 in the main canal, 1 in the weir box, and 1 downstream of the weir of the Control distributary canal.

[1] Type SAB600 from CR2M, France

Each water measurement section has been calibrated by current metering, wherever possible. Specific computer software was used in the processing. using the double integration method, as well'as for data management.

Table II. 1 of the sub-systems studied within the entire projects

P R O J E C T S Irrigation sub-systems studied	U P R I I S Santo Domingo Area (District I, zone 3)	G A L N E W A Kalankuttiya sub-system (Meegalewa Block)	K O I S P Kirindi Oya Right Bank	R A J A N G A N A Pilot area
PROGRAM AREA :				
. Whole project (ha)	106,500 ha	24,000 ha (6150 ha under LBMC)	12,900 ha (incl. 4500 ha of existing irrigation area)	7336 ha (3836 ha under LBMC)
. Sub-System studied (ha)	9,307 ha	2,020 ha	5000 ha (2630 ha in Phase I)	94 ha
Planted Area in Sub-system studied(ha)	8,055 ha	991 ha (49%)	2,630 ha (100%)	94 ha (100%)
STORAGE CAPACITIES :				
. Main Reservoir	PANTABANGAM DAM	KALAWEWA TANK	LUNUGAMWEHERA DAM	RAJANGANA TANK
. Gross storage (MCM)*	(3,000 MCM)	(123 MCM)	(226 MCM)	(100 MCM)
. Active storage (MCM)*	(2,750 MCM)		(198 MCM)	(95 MCM)
. Additional storage & capacities (between the main reservoir and the head of sub-system studied)	none	Mulannatuwa tank (0.63 MCM) Kalankuttiya tank (1.86 MCM)	none	none
WATER RESOURCE AVAILABILITY :				
. Storage at the start of the season	AUG 88: Exceptionally low (225 MCM)	MAY 88: Nearly Full (117 MCM)	NOV 87: medium (100 MCM) JAN 88: good (170 MCM)	Excellent throughout season
. Opportunities for supplementing the main reservoir	none	Yes, from the Mahaweli System through Polgolla diversion (Total inflow to Kalawewa from Mahaweli over the season 59 MCM)	none	Yes, from drainage of Mahaweli System H
. Opportunites for supplementing the sub-system studied from other source	Local flow from the Sapang Kawayan catchment	Kalankuttiya tank catchment area	Neglibible	LBMC upper catchment area
LOCATION OF THE SUB SYSTEM WITHIN THE ENTIRE SYSTEM :	Distance Km	Distance Km	Distance Km	Distance Km
. Sluice of the main reservoir	* Maniway Regulation Dam (Pampanga River) — 0	* Kalawewa LBMC — 0	* Kirindi Oya RBMC main sluice — 0	* Rajangana LBMC — 0
. Main branching points and intermediate tanks	* Rizal Dam (diversion to PRIS from — 13 * Headgate of DC1 (diversion canal no.1) — 16 * 3 major diversions RMA, VCIS, LTRS and a number of offtake. * SDA supply headgate diversion to the creek — 40	* 16 DC and FC offtakes along LBMC * Mulannatuwa tank — 19 * No diversion	- - -	* 3 FC & DC Offtakes — -
. Head work of the sub system	* SDA 5 bay check gate SDA headgate — 50	* Kalankuttiya BC Headgate — 24	* Coincides with RBMC main sluice — 0	* DC1 LB tract 2 offtake from LB main canal — 5.6

* MCM - Million cubic meters

Table II.2 Physical characteristics of the canals studied

CANALS:	SANTO DOMINGO AREA MAIN CANAL	KALANKUTTIYA BRANCH CANAL	KIRINDI OYA RIGHT BANK MAIN CANAL	RAJANGANA PILOT D-CANAL*
Commissioned on :	1976	1978	1986	1987
Type :	Double bank main canal, earth	Double bank canal, earth	Trapézoidal main canal, earth	Distributory canal, earth
Length :	24.4 km	10.9 Km	24.5 Km	1.3 Km
Max. Discharge Capacity(at head):	20.0 m3/s	5.66 m3/s	13.0 m3	0.3 m3/s
Average Slope :	0.9 m per Km	1.4 m per Km	0.3 m per Km	n.a
HEAD WORK				
. Number of gates Nb. operated	. 4 Headgate (+5 Bay CHGT) 0 Headgate (+2 at 5 Bay)	. 3 gates but only 1 manually operated	. 1 sluice gate electric	at le
. Measuring device Calibration	. Concrete Parshall Flume 15 ft NIA's Table questionable	. Gauging station(100 m d/s) Calibrated by current meter	. Gate opening meter. Theoretical equation	r p 1 co
REGULATING STRUCTURES				
. Main regulator, number and Type	. 11 cross-regulator undershot gated type (6 only w/gate operated)	. 9 duck-bill weirs 1 gated cross regulator	. 14 cross-regulators gated type plus side-walls 1 not operational	-bi
Total number of bays	23	2	61	0
Total number of gates	10	2	61	0
Total number of gates operated	6	2	n.a.	0
. Other cross-structures	. 35 Tresher crosser (or road crosser w/check operated with flashboards or banana trunks)	. 2 drop structures	none	non
Total number of bays(total)	66	0		
Total number of gates	1 (closed at all times)			
. Potential for intervention across the main canal	69	2	61	
. Density of gate + check per Km	3.6 per km	0.2 per km	2.5 per Km	0
DIVERSION STRUCTURES				
. Main Lateral	11 (Lateral A to J + Ex)	0	1 (BC#2)	
Total number of bays	13	-	1	
Total number of gates	12	-	1	
Total nb. of gates operational	7	-	1	
Measuring devices	11 Parshall flumes (CPF) (NIA Tables questionable: siltation, backwater, etc.)	-	1 (weir box) (submergence: partial control)	
. Other offtakes		-		
Baffle distributors	-	-		9
operating as/design				(6 operates as per desigr
Single gate turnout	26	20 (DC offtakes)		-
w/gate operational	12	19		-
w/measuring device	4 (CPF not operated)	13 weir boxes		-
Double gate turnout(C.H.O)	24	(but 8 calib. not reliable)		
w/2 gates	0			
w/1 gate operational	4			
w/measuring device	0			
Illegal	9 Reinforced concrete pipe (no measuring device)	0	n.a.	
. Total number of diversions	70	20	33	9
. Density of diversion per Km	2.9 per km	1.8 per km	1.3 per km	6.9 per Km

n.a = not available

* The Pilot is actually a Distributory canal taking off the main canal which is itself a single bank canal.

Table **IV.4** Kirindi Oya Right Bark Main Canal system: Record of daily rainfall and daily main sluice discharges

Date	Main sluice Discharges m^3/s	Daily Rainfall (mm)	
		L,wehera	Wirawila
19-Mar	4.81	0	0
20-Mar	5.38	12	14
21-Mar	6.23	7	6
22-Mar	5.66	0	0
23-Mar	5.09	0	0
24-nar	5.38	0	0
25-Mar	5.94	0	0
26-Mar	5.94	0	0
27-Har	5.94	32	0
28-Mar	5.94	0	[illegible]
29-Mar	5.52	0	[illegible]
30-Mar	5.52	6	18
31-Mar	5.52	0	0
01-Apr	5.52	0	0
02-Apr	5.52	0	0
03-Apr	5.52	0	0
04-Apr	5.23	0	0
05-Apr	5.23	0	0
06-Apr	5.23	0	0
07-Apr	5.23	0	0
08-Apr	5.23	0	0
09-Apr	5.09	13	80
10-Apr	0.56	8	2
11-Apr	0.56	21	0
12-Apr	0.00	30	3
13-Apr	0.00	9	14
14-Apr	0.00	23	2
15-Apr	0.00	0	1
16-Apr	0.00	0	3
17-Apr	2.83	0	0
18-Apr	4.95	0	0
19-Apr	4.95	0	4
20-Apr	4.95	0	0
21-Apr	4.95	0	0
22-Apr	4.95	0	0
23-Apr	4.95	9	0
24-Apr	4.95	1	0
25-Apr	4.95	0	0
26-Apr	4.95	3	0
27-Apr	4.95	6	55
28-Apr	4.95	0	58
29-Apr	4.95	0	0
30-Apr	4.95	0	0
01-May	4.45	0	0
02-May	4.45	0	0
03-May	4.45	0	0
04-May	4.45	0	0
05-May	4.45	0	0
06-May	2.83	0	0
07-May	2.83	0	0
08-May	2.83	0	2
09-nay	2.83	0	0

Date	Main sluice Discharges m^3/s	Daily Rainfall (mm)	
		L,wehera	Wirawila
10-May	3.39	0	0
11-May	3.39	0	0
12-May	3.68	0	0
13-May	4.24	0	0
14-May	4.24	0	0
15-May	4.24	0	0
16-May	4.24	0	0
17-May	4.24	0	0
18-May	5.09	0	0
19-May	5.09	0	3
20-May	4.81	0	0
21-May	4.53	0	0
22-May	4.53	0	0
23-May	4.53	0	0
24-May	4.53	0	0
25-May	4.53	0	0
26-May	4.53	0	0
27-May	4.53	3	0
28-May	3.11	0	0
29-May	3.11	0	0
30-May	3.11	0	0
31-May	3.11	0	0
01-Jun	3.11	8	7
02-Jun	2.83	0	11
03-Jun	2.83	0	5
04-Jun	2.83	0	0
05-Jun	2.83	2	1
06-Jun	2.26	2	0
07-Jun	2.26	0	0
08-Jun	2.26	0	0
09-Jun	2.26	0	4
10-Jun	2.26	0	0
11-Jun	2.26	0	0
12-Jun	2.69	0	0
13-Jun	2.69	0	0
14-Jun	2.69	0	0
15-Jun	2.69	0	0
16-Jun	2.26	0	0
17-Jun	2.26	0	0
18-Jun	2.26	0	0
19-Jun	2.26	0	0
20-Jun	2.26	0	0
21-Jun	2.26	0	0
22-Jun	2.26	0	0
23-Jun	2.26	0	0
24-Jun	2.26	0	0
25-Jun	2.26	0	2
26-Jun	1.98	0	0
27-Jun	1.98	0	0
28-Jun	1.98	0	0
29-Jun	1.98	0	0
30-Jun	1.98	0	0

Table IV.5
Kalanhuttiya branch canal: Summary of main sluice gate interventions, Yala 1988

Rotation	Starting date of rotation	Ending date of rotation	Duration (days)	Number of gate interventions: Opened	Increased	Reduced	Closed	Total	Remarh
tP	08/05/88	22/05/88	15	2	8	5	2	17	Closed on 17/05/88. But reopened on 20/05/88 for special issue to Meegalawa. Closed again on the same day
R1	23/05/88	30/05/88	8	I	4	2	I	8	Closed on 26/05/88
R2	31/05/88	07/06/88	8	I	3	3	I	8	Closed on 03/06/88
R3	06/06/88	20/06/88	13	2	8	5	2	17	Closed on 09/06/86 due to rain. But reopened on 11/06/88 to issue Meegalawa. Closed again on 16/06/88
R4	21/06/88	27/06/88	7	1	4	5	1	11	Closed on 24/06/88
R5	26/06/88	04/07/88	7	1	2	I	I	5	Closed on 01/01/88
R6	05/07/86	14/07/88	10	I	0	0	I	2	Closed on 06/07/88 due to rain
R7	15/07/88	24/07/88	10	I	2	1	I	5	Closed on 18/07/66
R8	25/07/88	01/08/88	8	2	1	3	2	8	Closed on 28/07/88. But reopened on the same day for special issue to Meegalawa. Closed again on 29/07/86
R9	02/08/88	09/08/88	5	I	3	3	I	8	Closed on 06/08/88
R10	10/08/88	18/08/88	9	1	I	0	1	3	Closed on 11/08/88 due to rain
R11	19/08/88	05/07/86	18	1	0	0	1	2	Could not manipulate the gate as it was broken. Closed On 24/08/88
R12	06/09/88	20/09/88	15	1	2	I	I	5	Closed on 09/09/68
R13	21/09/88	25/09/88	5	1	3	2	I	7	Closed on 26/09/88
Total ===>			141	17	41	31	17	106	
Percentage of total ==============>				16%	39%	29%	16%		

Interventions to maintain targets (usually to compensate drop in tanh water level) = 09 (09 %)
Interventions to change targets = 63 (59 %)
Openings and closures = 34 (32 %)

Table **IV.6**

Water levels and corresponding discharge **rates** recorded **at** staff gauge **MS1**

Uate	lime	Gauge (m)	Oischarge (m3/s)	Uate	line	Gauge (m)	Oischarge (m3/s)	Date	line	Gauge (m)	Oischarge (m3/s)	Oate	Time	Gauge (m)	Oischarge (m3/s)
08-Way	00:00	0.13	0.421	10-May	00:00	1.08	1.558	12-Way	00:00	1.22	2.096	14-May	00:00	1.30	2.390
08-Kay	01:00	0.13	0.427	10-May	01:00	1.08	1.558	12-Way	01:00	1.22	2.096	14-Way	01:00	1.30	2.390
08-May	02:00	0.13	0.427	10-May	02:00	1.08	1.546	12-May	02:00	1.22	2.096	14-May	02:00	1.30	2.319
08-May	03:00	0.13	0.421	10-Way	03:00	1.08	1.546	12-May	03:00	1.22	2.096	14-May	03:00	1.30	2.319
08-May	04:00	0.13 .	0.427	10-Way	04:00	1.08	1.546	12-May	04:00	1.22	2.096	14-May	04:00	1.30	2.319
08-Hay	05:00	0.13	0.427	10-May	05:00	1.08	1.535	12-Way	05:00	1.22	2.096	14-May	05:00	1.30	2.319
08-lay	06:00	0.13	0.421	10-May	06:00	1.08	1.535	12-Way	06:00	1.22	2.096	14-Kay	06:00	1.30	2.319
08-Kay	07:00	0.13	0.421	10-May	07:00	1.01	1.524	12-May	07:00	1.22'	2.096	14-May	07:00	1.30	2.319
08-May	08:00	0.13	0.421	10-May	08:00	1.07	1.521	12-lay	08:00	1.22	2.096	14-Hay	08:00	1.30	2.319
08-May	09:00	0.73	0,421	10-Kay	09:00	1.07	1.521	12-May	09:00	1.20	2,053	14-Kay	09:00	1.30	2.319
08-Hay	10:00	0,85	0.722	10-May	10:00	1.01	1.524	12-Hay	10:00	1.23	2.152	14-lay	10:00	1.30	2.319
08-Kay	11:00	0.88	0.190	10-Kay	11:00	1.01	1.524	12-May	11:00	1.23	2.152	14-May	11:00	1.30	2.319
08-Ray	12:00	0,87	0.156	10-May	12:00	1.08	1.535	12-lay	12:00	1.21	2.164	14-Kay	12:00	1.30	2.319
08-Way	13:00	0.81	0.156	10-May	13:00	1.25	2.209	12-May	13:00	1.24	2.164	14-Way	13:00	1.30	2.319
08-Kay	14:00	0.81	0.156	10-May	14:00	1.28	2.334	12-May	14:00	1.24	2.175	14-Kay	14:00	'1.30	2.319
08-Way	15:00	0.81	0.156	10-May	15:00	1.30	2.319	12-May	15:00	1.24	2.175	14-May	15:00	1.30	2.319
08-May	16:00	0.81	0.156	10-Kay	16:00	1.30	2.319	12-May	16:00	1.24	2.164	14-Kay	16:00	1.30	2.319
08-May	17:00	0.81	0.156	10-May	17:00	1.30	2.390	12-May	17:00	1.24	2.186	14-May	17:00	1.30	2.319
08-May	18:00	0.86	0.139	10-Kay	18:00	1.30	2.390	12-May	18:00	1.24	2.186	14-May	18:00	1.29	2.368
08-Way	19:00	0.86	0.139	10-Kay	19:00	1.30	2.379	It-May	19:00	1.21	2.184	14-Way	19:00	1.29	2.356
08-Hay	20:00	0.86	0.139	10-May	20:00	1.30	2.319	12-May	20:00	1.24	2.181	14-May	20:00	1.29	2.356
08-Way	21:00	0.86	0.139	10-May	21:00	1.30	2.319	12-May	21:00	1.23	2.152	14-Way	21:00	1.29	2.345
08-May	22:00	0.86	0.739	10-May	22:00	1.30	2.319	12-May	22:00	1.23	2.152	14-Way	22:00	1.29	2.345
08-May	23:00	0.86	0.139	10-May	23:00	1.29	2.368	12-Way	23:00	1.23	2.152	14-May	23:00	1.29	2.315
09-Hay	00:00	1.01	1.501	11-Kay	00:00	1.29	2.368	13-May	00:00	1.13	2.152	15-Kay	00:00	1.28	2.334
09-Way	01:00	1.08	1.558	It-Way	01:00	1.29	2.368	13-Way	01:00	1.23	2.152				
09-Way	02:00	1.10	1.614	Il-Way	02:00	1.29	2.368	13-Way	02:00	1.23	2.152				
09-Way	03:00	1.10	1.614	Il-May	03:00	1.29	2.356	13-May	03:00	1.23	2.152				
09-Hay	04:00	1.10	1.614	11-Hay	04:00	1.29	2.356	13-May	04:00	1.23	2.152				
09-May	05:00	1.10	1.614	Il-May	05:00	1.29	2.356	13-May	05:00	1.23	2.152				
09-May	06:00	1.10	1.614	Il-Way	06:00	1.29	2.356	13-Kay	06:00	1.23	2.152				
09-Hay	07:00	1.10	1.614	Il-Way	07:00	1.29	2.345	13-Kay	07:00	1.23	2.152				
09-May	08:00	1.10	1.614	Il-Nay	08:00	1.28	2.331	13-May	08:00	1.23	2.152				
09-May	09:00	1.10	1.614	Il-May	09:00	1.23	2.152	13-May	09:00	1.23	2.152				
09-Hay	10:00	1.12	1.128	11-May	10:00	1.23	2.152	13-May	10:00	1.22	2.096				
09-May	11:00	1.12	1.128	II-Hay	11:00	1.40	2.911	13-Kay	11:00	1.22	2.096				
09-Hay	12:00	1.11	1.685	It-Hay	12:00	1.27	2.266	13-May	12:00	1.22	2.096				
09-Hay	13:00	1.09	1.592	11-May	13:00	1.22	2.096	13-Way	13:00	1.30	2.319				
09-Way	14:00	1.09	1.580	Il-Way	14:00	1.20	2.053	13-May	14:00	1.31	2.424				
09-Hay	15:00	1.09	1.569	11-May	15:00	1.22	2.096	13-Way	15:00	1.31	2.436				
09-Hay	16:00	1.08	1.558	Il-May	16:00	1.22	2.096	13-May	16:00	1.31	2.436				
09-May	17:00	1.08	1.558	11-May	17:00	1.23	2.152	13-Way	17:00	1.31	2.136				
09-Hay	18:00	1.08	1.558	Il-Way	18:00	1.23	2.152	13-May	18:00	1.31	2.424				
09-Hay	19:00	1.09	1.569	11-Hay	19:00	1.22	2.096	13-Way	19:00	1.30	2.113				
09-May	20:00	1.09	1.569	11-May	20:00	1.22	2.096	13-Kay	20:00	1.30	2.402				
09-May	21:00	1.08	1.558	11-May	21:00	1.22	2.096	13-May	21:00	1.30	2.390				
09-May	22:00	1.08	1.558	11-Kay	22:00	1.22	2.096	13-Kay	22:00	1.30	2.390				
09-May	23:00	1.08	1.558	Il-May	23:00	1.22	2.096	13-Kay	23:00	1.30	2.390				

Table lV.7

SDA - HEADGATE

Comparison of discharge estimate by current metering (Q_{meas}) and fron the NIA's table (Q_{NIA})

Date	Time	Q_{meas} (m^3/s)	H_a (cm)	H_b (cm)	H_b/H_a (%)	Reduc. Factor	Q(FF) (m^3/s)	Fit(FF) (m^3/s)	Q_{fit} (m^3/s)	Q_{meas} (m^3/s)	Q_{NIA} (m^3/s)	Diff.[1] (m^3/s)	Diff.[2] (%)
13-Aug-88	08:44	1.389	37.3	34.6	93	0.845	1.644	1.764	1.490	1.389	1.912	0.52	31.1
18-Aug-88	08:25	9.166	131.6	127.4	97	0.730	12.556	12.212	8.958	9.166	12.420	3.25	35.5
22-Aug-88	09:03	9.847	126.8	120.6	95	0.190	12.465	11.590	9.156	9.847	12.665	2.82	28.6
24-Aug-88	08:12	11.474	151.0	143.2	95	0.790	14.514	15.164	11.979	11.474	16.748	5.21	46.0
30-Aug-88	09:28	4.263	76.0	70.5	93	0,845	5.045	5.213	4.455	4.263	5.972	1.11	40.1
31-Aug-88	08:39	5.702	92.0	90.0	98	0.100	8.146	7.075	4.952	5.702	6.716	1.01	11.8
06-Sep-88	09:02	5.499	79.0	68.0	86	0.960	5.128	5.596	5.372	5.499	1,219	1.72	31.3
07-Sep-88	11:17	5.129	78.0	69.0	88	0.930	5.515	5.488	5.103	5.129	6.852	1.72	33.6
21-Sep-88	09:00	4.557	68.0	53.0	78	1.000	4.551	4.143	4.443	4.557	5.916	1.36	29.8
22-Sep-88	08:52	3.266	54.0	35.0	65	1.000	3.266	3.116	3.116	3.266	4.091	0.82	15.3
23-Sep-88	09:40	1.386	32.5	3.0	9	1.000	1.386	1.421	1.427	1.386	1.815	0.43	31.0
27-Sep-88	10:00	1.291	30.0	19.0	63	1.000	1.291	1.261	1.261	1.291	1.591	0.31	23.1
29-Sep-88	08:48	1.917	38.0	28.0	74	1.000	1.911	1.815	1.815	1.917	2.332	0.41	21.6

[1]Diff. = $Q_{NIA} - Q_{meas}$

[2]Diff.(%) = Diff./Q_{meas}

$Q_{fit}(FF) = RF*0.006731*H_a^{1.538668}$

H_a = Head upstream of throat

H_b = Head downstream of throat

Reduction factors (RF) due to submergence of Parshall flume.

H_b/H_a (%)	Reduc. Factor	H_b/H_a (%)	Reduc. Factor
0 - 79	1.000	90	0.900
80	0.990	91	0.885
81	0.990	92	0.870
82	0.990	93	0.845
83	0.980	94	0.820
84	0.970	95	0.790
85	0.960	96	0.760
86	0.960	97	0.730
87	0.945	98	0.700
88	0.930	99	NA
89	0.915	100	NA

Note to be read in conjunction with Tables IV.7, IV.12 and IV.13.

Calibration of Parshall flumes at **SDA**

The discharge across a Parshall flume under free flow conditions is a function of the head upstream of the throat (H_a). However, when the submergence (computed from H_b/H_a where H_b is the head downstream of the throat) increases above 70%, the discharge is obtained by the application of a reduction factor to the free flow discharge. These reduction factors are available (from the tables used by the agency) for a submergence ranging from **70%** to **98%.** For Parshall flumes of throat width 10 feet and above these reduction factors are applied only after the submergence reaches 80%.

During calibration of the Parshall flumes it was noted that at some instances the flumes were submerged. Hence the discharges obtained from the measurements that were done under submerged conditions were corrected (i.e. increased) to their corresponding free flow discharges (actually a reverse process of applying the reduction factors) and a curve was fitted to this set of free flow values. For example, if the measured discharge is 5 m^3/s and the submergence is 95%, giving a reduction factor of **0.79** for a **15** foot Parshall flume, the free flow discharge is computed as **5/0.79 = 6.33 m^3/s.**

The use of the calibration curve for the Headgate and Lateral B yields estimates of the free flow discharge for the given value of H_a. If the degree of submergence is above the allowable value for the particular throat width the corresponding reduction factor should be applied. Here the free flow discharge would be multiplied by the corresponding reduction factor to obtain the actual discharge.

In the case of Lateral **G,** since only the head upstream of the throat was monitored, a curve was fitted to the measurements done without considering the effect of submergence, Hence in this case the discharge could be directly obtained from the calibration curve. But given the dispersion of the measured points (see calibration curve), discharge computations at Lateral G could sometimes be erroneous, depending on the degree of submergence prevailing at that time.

Table IV.8

Daily discharge rates and volumes distributed near SDA Lateral B, during 21 July to 7 October 1988.

Date	SDA-U/S Lateral B 7031 ha				SDA-D/S Lateral B 4178 ha				SDA- Lateral B 2852 ha			
	m3/s	m3/ day	mm/ day	mm/ Subtotal	m3/s	m3/ day	mm/ day	mm/ Subtotal	m3/s	m3/ day	mm/ day	mm/ Subtotal
21-Jul	3.8	329,352	4.7		1.1	99,227	2.4		2.7	230,125	8.1	
22-Jul	2.9	252,537	3.8		1.4	117,534	2.8		1.6	135,003	4.7	
23-Jul	2.2	187,813	2.1		0.9	75,046	1.8		1.3	112,787	4.0	
24-Jul	2.2	192,136	2.7	13.7	1.2	101,387	2.4	9.4	1.1	90,749	3.2	19.9
25-Jul	7.0	603,098	8.6		3.3	287,686	6.9		3.7	315,412	11.1	
26-Jul	6.2	538,187	7.7		3.1	266,072	6.4		3.1	272.095	9.5	
27-Jul	9.9	853,255	12.1		4.9	420,308	10.1		5.0	432.867	15.2	
28-Jul	9.7	837,373	11.9		5.8	504,585	12.1		3.9	332,188	11.7	
29-Jul	8.8	762.752	10.8		5.7	495,139	11.9		3.1	267,613	9.4	
30-Jul	8.7	747,783	10.6	61.6	5.2	447,470	10.7	58.0	3.5	300,313	10.5	87.4
31-Jul	3.7	317,395	4.5		2.4	205,439	4.9		1.3	111,956	3.9	
01-Aug	3.5	305,607	4.3		1.6	136,859	3.3		2.0	168.948	5.9	
02-Aug	3.1	286,153	3.8		1.2	106,912	2.6		1.8	159,241	5.6	
03-Aug	1.9	161,441	2.3		1.2	107.716	2.6		0.6	53,725	1.9	
04-Aug	1.5	133,350	1.9	18.8	1.0	89,383	2.1	15.5	0.5	43.987	1.5	18.9
05-Aug	6.9	598,602	8.5		4.0	344,744	0.3		2.9	251,858	8.8	
06-Aug	7.8	671,915	9.6		4.4	316,530	9.0		3.4	295.385	10.4	
07-Auy	9.1	786,199	11.2		4.8	411.488	10.0		4.3	368,712	12.9	
08-Aug	6.3	541,842	1.7		3.6	310,713	7.4		2.7	231,129	8.1	
09-Rug	6.2	536,443	7.6		3.3	280,842	6.7		3.0	255,601	9.0	
10-Aug	4.9	420,637	6.0		3.0	258,638	6.2		1.9	102.000	5.1	
11-Aug	2.7	236,130	3.4	53.9	2.1	182,576	4.4	52.0	0.8	53,553	1.9	56.7
12-Aug	1.7	146,150	2.1		1.0	84,887	2.0		0.7	61,263	2.1	
13-Aug	1.3	113,475	1.6		0.7	59,869	1.4		0.6	53,606	1.9	
14-Aug	0.9	80,302	1.1		0.4	37,339	0.9		0.5	42.962	1.5	
15-Aug	0.8	66,132	0.9		0.4	35,203	0.8		0.4	31,529	1.1	
16-Aug	1.9	161,150	2.3	8.1	0.6	48,299	1.2	6.4	1.3	112,052	4.0	10.8
17-Aug	4.4	380,382	5.4		1.7	143,074	3.4		2.7	237,309	8.3	
18-Aug	6.1	525,122	7.5		2.7	236,121	5.7		3.4	289,801	10.2	
19-Aug	7.0	800,647	8.5		4.2	365,493	8.7		2.1	235.154	0.2	
20-Aug	7.3	629,696	9.0		4.4	380,175	9.1		2.9	249,520	8.7	
21-Aug	1.3	633,873	9.0		4.4	302,194	9.1		2.9	251,479	8.8	
22-Aug	7.0	602.769	8.6		4.3	369,255	8.0		2.7	233,514	8.2	
23-Aug	7.1	612.862	8.7		4.3	372.377	8.9		2.8	240,485	8.4	
24-Aug	8.2	712,489	10.1		4.8	411,095	9.0		3.5	301.394	10.6	
25-Aug	8.0	693,128	9.9		4.6	400,375	9.6		3.4	292,753	10.3	
26-Aug	5.8	503,770	1.2		3.7	321,141	7.7		2.1	182,628	8.4	
27-Aug	3.0	263.023	3.1	07.6	2.4	211.210	5.1	06.0	0.6	51.813	1.8	90.0
28-Aug	2.5	218,031	3.1		2.2	190.803	4.6		0.3	27,428	1.0	
29-Aug	2.1	179.881	2.6		1.7	145,099	3.5		0.4	34,789	1.2	
30-Pug	3.0	281.964	3.7		1.8	151,691	3.8		1.3	110,267	3.9	
31-Aug	3.3	288.421	4.1		1.7	147,976	3.5		1.8	140,445	4.9	
01-Sep	3.2	274,024	3.9		1.7	145.874	3.5		1.5	128,350	4.5	
02-SWD	2.1	184,006	2.6		1.5	131,548	3.1		0.6	52,458	1.8	
03-Sep	1.3	110,871	1.6		1.1	83,146	2.2		0.2	17,724	0.6	
04-Sep	2.2	192,192	2.7		1.5	133,840	3.2		0.7	58.352	2.0	
05-Sep	2.1	180.209	2.8		0.8	73,368	1.8		1.2	101,840	3.7	
06-Sep	2.7	236,076	3.4		0.6	48,753	1.2		2.2	181,323	6.6	
07-Sep	3.9	333,353	4.7	35.0	1.4	120.448	2.9	33.1	2.5	212,905	7.5	37.8

Table IV.8 (contd..)

Daily discharge rates and volumes distributed near SDA Lateral B, during 21 July to 7 October 1988.

Date	SDA-U/S Lateral B 7031 ha				SDA-D/S Lateral B 4178 ha				SDA- Lateral B 2852 ha			
	m3/s	m3/ day	mm/ day	mm/ Subtotal	m3/s	m3/ day	mm/ day	mm/ Subtotal	m3/s	m3/ day	mm/ day	mm/ Subtota
08-Sep	5.9	507,159	7.2		4.0	343,076	8.2		1.9	164,083	5.8	
09-Sep	6.7	580,368	8.3		5.7	491,374	11.8		1.0	80,991	3.1	
10-Sep	8.2	704,612	10.0		7.2	620,436	14.9		1.0	84,176	3.0	
11-Sep	6.4	550,005	7.8		5.8	504,010	12.1		0.5	45,996	1.6	
12-Sep till 8am	2.2	186,176	2.6	36.0	1.9	166,614	4.0	60.9	0.2	19,562	10.1	23.5
12-Sep from 8am	4.1	352,452	5.0		1.0	84,264	2.0		3.1	268,188	0.0	
13-Sep	6.0	516,647	7.3		1.1	91,674	2.2		4.9	424,973	14.9	
14-Sep till 8am	1.7	144,784	2.1	14.4	0.5	40,086	1.0	5.2	1.2	104,698	4.7	19.6
14-Sep from 8am	4.3	367,884	5.2		3.9	338,133	8.1		0.3	29,751	0.0	
15-Sep	7.3	630,609	9.0		6.6	566,395	13.6		0.7	64,214	2.3	
16-Sep	5.6	484,032	6.9		5.1	441,482	10.6		0.5	42,549	1.5	
17-Sep	2.2	190,838	2.7		2.1	184,314	4.4		0.1	6,524	0.2	
18-Sep	2.4	209,009	3.0		2.2	189,071	4.5		0.2	19,938	0.7	
19-Sep till 8am	1.0	89,295	1.3	28.0	0.7	62,781	1.5	42.7	0.3	26,514	[illegible]	11.3
19-Sep from 8am	2.0	171,567	2.4		0.1	8,309	0.2		1.9	163,258	0.0	
20-Sep	4.1	351,536	5.0		0.0	63	0.0		4.1	351,474	12.3	
21-Sep till 8am	1.0	86,363	1.2	8.7	0.0	2,481	0.1	3.0	1.0	83,882	4.1	16.4
21-Sep from 8am	1.8	157,303	2.2		1.5	125,371	3.0		[illegible]	31,932	0.0	
22-Sep	1.8	156,933	2.2		1.7	143,165	3.4		0.2	13,767	0.5	
23-Sep	1.3	114,025	1.6		1.2	106,496	2.5		0.1	[illegible]	[illegible]	
24-Sep	0.6	51,378	0.7		0.5	[illegible]	1.1		0.1	6,206	0.2	
25-Sep	1.4	117,532	1.7	8.5	1.3	111,327	2.7	12.7	0.1	6,206	0.2	1.2
26-Sep	0.8	68,486	1.0		0.3	24,879	0.6		0.5	43,606	1.5	
27-Sep	0.8	72,087	1.0		0.0	2	0.0		0.8	72,085	2.5	
28-Sep	1.2	105,334	1.5	3.5	0.8	71,112	1.7	2.3	0.4	34,222	1.2	5.3
29-Sep	2.1	183,762	2.6		1.8	151,656	3.6		0.4	32,106	1.1	
30-Sep	1.4	118,529	1.7		1.2	105,444	2.5		0.2	13,085	0.5	
01-Oct	0.6	51,195	0.7		0.5	44,989	1.1		0.1	6,206	0.2	
02-Oct	0.6	55,113	0.6	5.8	0.6	48,907	1.2	8.4	0.1	6,206	0.2	2.0
03-Oct	0.8	69,306	1.0		0.2	13,741	0.3		0.6	55,565	1.9	
04-Oct	1.7	147,869	2.1		0.0	5	0.0		1.7	147,863	5.2	
05-Oct	4.1	355,183	5.1		2.1	182,063	4.4		2.0	173,119	6.1	
06-Oct	8.9	766,995	10.9		5.2	447,264	10.7		3.7	319,730	11.2	
07-Oct	4.7	405,488	5.8	24.8	3.2	279,100	6.7	22.1	1.5	126,388	4.4	28.8
Total		28,582,838	406.5			16,907,652	404.7			11,675,184	409.4	
No. Day	79											
Daily mean		361,808	5.1			214,021	5.1			147,787	5.2	
(before 12 September)												
Total		21,805,129	310.1			12,831,291	307.1			8,973,838	314.7	
No. Day	53											
Daily mean		411,418	5.9			242,100	5.8			169,318	5.9	
(from 12 September)												
Total		6,777,708	96.4			4,076,361	97.6			2,701,346	94.7	
No. Day	26											
Daily mean		260,681	3.7			156,783	3.8			103,898	3.6	

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Table IV.9 SDA Main Canal.at the Lateral B branching point - 24 July to 31 July 1988
History of interventions and impact on flow sharing.

DATE	TIME	SDA MAIN CANAL Upstream of Lateral B m3/s	Downstream of Lateral B m3/s	%	LATERAL B m3/s	%	REMARKS
24 JULY	21:00	2.52	1.71	68	0.81	32	
Daily Average		2.21	1.17	53	1.04	47	
25 JULY	08:40	9.32	2.74	29	6.58	71	
	09:40	<......					Opening GR
	10:40	8.56	4.49	52	4.07	48	
Daily Average		6.98	3.33	48	3.65	52	
26 JULY	04:20	3.53	2.65	75	0.88	25	
	05:20	<......					Closure GR
	06:20	3.30	1.85	56	1.45	44	
Daily Average		6.23	3.08	49	3.15	51	
27 JULY	04:30	11.61	4.36	38	7.25	62	
	05:30	<......					Opening GR
	06:30	1.1.17	5.41	48	5.76	52	
Daily Average		9.88	4.87	49	5.01	51	
28 JULY	15:50	10.50	5.55	53	4.94	47	
	16:50	<......					Opening GR
	17:50	10.85	7.81	72	3.04	28	
Daily Average		9.96	5.84	59	3.85	39	
29 JULY	04:30	9.54	7.05	74	2.49	26	
	05:30	<......					Closure GR
	06:30	9.23	6.09	66	3.14	34	
	09:10	8.80	5.93	67	2.87	33	
	10:10	<......					Closure GR
	11:10	8.32	4.86	58	3.46	42	
Daily Average		8.83	5.73	65	3.10	35	
30 JULY	06:00	10.49	5.51	53	4.98	47	
	18:00	7.74	5.03	65	2.71	35	
Daily Average		8.66	5.18	60	3.48	40	
31 JULY	04:30	4.62	3.80	82	0.82	18	
	05:30	<......					Closure GR
	06:30	3.85	2.33	61	1.52	39	
Daily Average		3.67	2.38	65	1.30	35	
Average for the period 24-31 JULY: (8 days)		7.05	3.95	56	3.07	44	
Planted Area (ha) under command		7,031	4,178	59	2,852	41	

* The daily averages are computed from discharge records available at 10 minute intervals

Table IV. 10 Evaluation of Capacity to assess flow diverted at offtakes, Kalankuttiya Branch Canal - Yala 1988

CHANNEL	PHYSICAL CONDITIONS CORRECT (WEIR)	HYDRAULIC CONDITIONS CORRECT (FREE FLOW)	MEASURING DEVICE CORRECT	SENSITIVITY *
30801	No			N.A
30901		No		N.A
30904	(15%)		No	N.A
308D2		(30%)		N.A
30803			(35%)	N.A
30902				N.A
306D2				N.A
305D1				22%
305D2				9% **
306D1		Questionable	Questionable	21%
307D3	Yes			24%
306D4		40%	40%	N.A
307D1	(85%)			16%
307D2				17%
306D5				23%
305D3				20%
305D4		Yes	Yes	22%
306D3				N.A
309D3		(30%)	(25%)	23%
309D5				18%

* Relative variation of discharge for a variation of 1 cm reading of the scale.

** The measuring device at this location is a trapezoidal contracted weir instead of the usual broad-crested weir.

Tabla IV. 11 Kirindi Oya Right Bank lain Canal, Physical Condition of Structures

	OFFTAKE/ REGULATOR	DISTANCE FROM MAIN SLUICE (m)	RELATIVE DISTANCE: FROM D/S REGULATOR (m)	OFF TAKE DIAMETER (m)	PHYSICAL CONDITIONS CORRECT (WEIR)
	FC6	935	,1480	00.30	Y
T	DC2	1592	823	00.60	Y
R	DC3)	(U/S)2408	1	00.60	N
A	DC3)*	(D/S)2408	1	00.60	
C	GR2	2415	0	- -	
T	DC4	2911	1035	00.15	Y
	DC5	3967	15	00.60	N
	GR3	4012	0	- -	
O	FC55	5316	1691	00.30	N
N	FC56	5482	1525	00.30	N
E	FC57	5949	1058	00.30	Y
	FC58	6918	29	00.30	Y
	GR4	7007	0	- -	
	DC1	8515	35	00.45	N
	C85	8550	0	- -	
T	DC2	10511	21	00.15	Y
R	GR6	10532	0	- -	
A	DC3	11701	328	00.45	N
C	FC34	11997	32	00.30	Y
T	GR7	12029	0	- -	
	DC4	13145	587	00.37	Y
	DC5	13715	17	00.45	Y
T	GR8	13132	0	- -	
W	DC6	14594	513	00.60	N
O	DC7	14911	160	00.45	Y
	GR9	15137	0	- -	
	FC68	15229	931	00.30	N
	DC8	16142	24	00.45	N
	GR10	16166	0	- -	
	DC9	17788	324	00.45	N
	DC18	18017	95	00.30	Y
	GR11	18112	0	- -	
	DC1	18920	940	00.45	Y
T	DC1A	19365	495	00.31	Y
R	BC2	19812	48	1,12(W)x1,05(H)	Y
A	GR12	19860	0	- -	
C	FC48	20108	2002	00.30	Y
T	FC49	21316	794	00.30	Y
	DC9	21698	412	00.45	Y
	FC54A	21858	252	00.30	Y
F	FC54	22094	16	00.30	Y
I	GR13	22110	0	- -	
V	FC55	22906	436	00.30	Y
E	DC11	23311	28	00.61	Y
	GR14	23342	0	- -	
	DC12	24282	199	00.15	Y
	DC13	24158	23	00.60	Y
	GR15	24481	0	- -	
					23 - Y
					10 - N

* DC3 has two openings
CR : Gated Cross Regulator   CRI : is not operational

Table IV.12

SOA - LATERAL B

Comparison of discharge estimate by current metering (Q_{meas}) and from the NIA's table (Q_{NIA})

Date	Time	Q_{meas} (m^3/s)	H_a (cm)	(cm)	H_t/H_a (%)	Reduc. Factor	Q(FF) (m^3/s)	Q_{fit}(FF) (m^3/s)	Q_{fit} (m^3/s)	Q_{meas} (m^3/s)	Q_{NIA} (m^3/s)	Diff.[1] (m^3/s)	Diff. (%)
15-Aug-88	10:14	0.684	24.1	6.9	29	T.000	0.684	0.572	0.572	0.684	0,T66	0.08	12.04
16-Aug-88	10:11	2.080	45.4	39.1	86	0.960	2.167	1.937	1.860	2.080	2.026	-0.05	-2.57
18-Aug-88	10:45	3.260	67.2	62.3	93	0.845	3.858	4.122	3.483	3.260	3.341	0.08	2.47
22-Aug-88	09:53	2.840	57.3	52.5	92	0.870	3.264	3.033	2.639	2.840	2.665	-0.17	-6.15
24-Aug-88	10:12	3.480	63.7	57.3	90	0.900	3.867	3.719	3.347	3.480	3.266	-0.TT	-6.14
25-Aug-88	15:10	3.570	70.4	62.9	89	0.915	3.902	4.509	4.125	3.570	3.897	0.33	9.16
26-Aug-88	11:50	2.140	47.9	35.1	73	1.000	2.140	2.148	2.148	2.140	2.300	0.16	7.47
30-Aug-88	10:25	1.150	33.4	-8.2	-25	T.000	1.150	1.073	1.073	1.150	T.T92	0.14	12.33
31-Aug-88	10:33	1.540	43.7	ƎI.Ǝ	86	0.960	1.604	1.800	1.728	1.540	T.906	0.37	23.80
01-Sep-88	11:23	2.220	45.8	34.2	75	1.000	2.220	1.970	T.9T0	2.220	2.141	-0.08	-3.57
06-Sep-88	10:29	2.620	49.8	TZ,8	86	0.960	2.729	2.315	2.223	T.6T0	2.350	-0.27	-10.31
07-Sep-88	10:31	3.890	66.5	53.3	80	0.990	3.929	4.040	4.000	3.890	3.849	-0.04	-1.06
26-Sep-88	10:19	0.325	20.0	-8.7	-44	T.000	0.325	0.400	0.T00	0.325	0.569	0.24	74.96
27-Sep-88	11:04	1.310	41.5	34.5	83	0.980	1.337	1.630	1.597	1.310	1.792	0.48	36.78

[1]Diff. = $Q_{NIA} - Q_{meas}$

[2]Diff.(%) = Diff./Q_{meas}

$Q_{fit}(FF) = RF*0.00125*H_a^{1.9253}$

H_a = Head upstream of throat

H_b = Head downstream of throat

Reduction factors (RF) due to submergence of Parshall flume.

H_b/H_a (%)	Reduc. Factor	H_b/H_a (%)	Reduc. Factor
0 - 79	1.000	90	0.900
80	0.990	91	0.885
81	0.990	92	0.870
82	0.990	93	0.845
83	0.980	90	0,8T0
84	0.970	95	0.790
85	0,960	96	0.760
86	0,960	97	0.730
87	0.945	98	0.T00
88	0.930	99	NA
89	0.915	100	NA

Table IV.13

SDA - LATERAL G

Conparison of discharge estimate by current metering (Q_{meas}) and fron the NIA's table (Q_{NIA})

Oate	Time	Q_{meas} (m^3/s)	H_a (cm)	H_b (mm)	H_b/H_a (%)	Reduc. Factor	Q(FF) (m^3/s)	Q_{fit}(FF) (m^3/s)	Q_{fit} (m^3/s)	Q_{meas} (m^3/s)	Q_{NIA} (m^3/s)	Diff.[1] (m^3/s)	Diff.[2] (%)
16-bug-88	13:50[3]	0.219	49.1	H_b values not available					0.485	0.279	0.962	0.68	244.19
18-Aug-88	13:20[3]	0.608	68.2						0.932	0.608	1.616	1.01	165.11
24-Aug-88	13:38[3]	0.574	60.5						0.735	0.574	1,331	0.16	132.97
31-Aug-88	13:59[3]	0.151	36.3						0.266	0.151	0.597	0.45	295.56
23-Sep-88	13:15	0.603	55.7						0.623	0.603	1.114	0.57	94.65
30-Sep-88	14:10	0.278	37.4						0.282	0.278	0.626	0.35	125.21
30-Sep-86	13:20	0.491	46.8						0.441	0.491	0.892	0.40	81.63
30-Sep-88	11:27[3]	0.192	57.1						0.655	0.192	1.221	1.03	535.15
30-Sep-88	10:45	0.987	71.1						1.013	0.987	1.125	0.14	14.80
30-Sep-88	09:56	0.169	29.3						0.174	0.169	0.426	0.26	152.06

[1] $Diff. = Q_{NIA} - Q_{meas}$

[2] $Diff.(\%) = Diff./Q_{meas}$

[3] These points were eliminated when fitting the calibration equation

$$Q_{fit} = 0.00021 * H_a^{1.989}$$

H_a = Head upstream of throat

H_b = Head downstream of throat

Table IV.14

Daily water delivery statistics, SDA Lateral B, 21 July to 07 October 1988.

Date	Rate of Discharge									Volume of Discharge		
	Average (m3/s)			STD (m3/s)			CV			Total (m3)		
	QMCD	0T8E	0T8T	QMCD	0T8E	QLBT	QMCD	QLBC	QLBT	VMCD	VLBC	VLBT
21-Jul	T.TT8	2.663	2.747	0.27	0.31	0.26	0.23	0.11	0.09	99,ZZT	230,125	237,358
22-Jul	1.360	1.563	1.749	0.47	0.61	0.53	0.35	0.39	0.30	117,534	135,003	151,120
23-Jul	0,869	1.305	1.519	0.02	0.12	0.12	0.02	0.09	0.08	75,046	112,767	TTT.Z6T
24-Jul	T.TTT	1.050	1.268	0.46	0.43	0.13	0.40	0.13	0.11	101,387	90,749	109,529
25-Jul	3.330	3.651	3.478	0.77	1.75	T.T9	0.23	0.48	0.40	287,686	315,412	300,498
26-Jul	3.080	3.149	3.020	0.81	2.30	1.83	0.26	0.73	0.61	266,072	272,095	260,916
27-Jul	4.865	5.010	4.557	0.90	1.60	1.18	0.10	0.32	0.26	420,368	432,887	393,747
28-Jul	5.840	3.852	3.717	1.32	0.59	0.46	0.23	0.15	0.12	504,585	332,788	321,124
29-Jul	5.731	3.097	3.115	1.01	0.27	0.23	0.18	0.09	0.07	495,139	267,613	269,100
30-Jul	5.179	3.476	3.382	0.35	1.02	0.83	0.07	0.29	0.24	447,470	300,313	T9T.T80
31-Jul	2.378	T,T96	1.500	0.81	0.38	0.38	0.34	0.29	0.25	205,439	111,956	TT9,T9T
01-Aug	1.582	1.955	2.111	0.61	0,70	0.61	0.39	0.36	0.29	136,659	T68,9T8	182,380
02-Aug	1.237	1.843	2.005	0.37	0.77	0.67	0.30	0.42	0.33	106,912	TT9,TTT	173,215
03-Aug	1.247	0.622	0.812	0.17	0.25	0.27	0.14	0.40	0.33	107,716	53,725	T0,TT9
04-Aug	1.034	0.509	0,668	0.39	0.53	0.51	0.38	1.05	0.76	89,363	43,987	57,704
05-Aug	3.990	2.915	T,866	T,96	1.26	1.08	0.49	0.43	0.38	344,744	251,858	247,585
06-Aug	4.358	3.419	3.248	0.23	1.61	1.31	0.05	0.47	0.40	376,530	T9T.T8T	280,607
07-Aug	4.832	4.267	3.909	0,J0	1.93	1.47	0.06	0.45	0.38	417,488	368,712	337,758
08-Aug	3.596	2.675	T,68T	0.39	1.31	1.12	0.11	0.49	0.42	310,713	231,129	231,676
09-Aug	3.250	T,9T8	2.954	0.25	0.81	0.67	0.08	0.28	0.23	280,842	255,601	255,239
10-Aug	2.993	1.875	2.020	0,T6	0.65	0.58	0.05	0.35	0.29	258,638	162,000	174,553
11-Aug	2.113	0.620	0,809	0.46	0.25	0.28	0.22	0.41	0.35	182,576	53,553	69,888
12-Aug	0.982	0,T09	0,908	0.35	0.23	0.25	0.36	0.32	0.28	84,887	61,263	78,461
13-Aug	0.693	0,620	0.803	0.09	0.39	0.39	0.12	0.63	0.49	59,869	53,606	69,393
14-Aug	0.432	0.497	0.674	0.11	0.22	0.24	0.25	0.43	0.36	37,339	42,962	58,204
15-Aug	0.407	0.365	0.498	0.16	0.30	0,J7	0.40	0.82	0.74	35,203	31,529	43,013
16-Aug	0.559	1.306	1.475	0.10	0.68	0,69	0.17	0.52	0.47	T8,Z99	112,852	127,423
17-Aug	1.656	2.747	2.762	0.58	0.33	0.27	0.35	0.12	0.10	143,074	237,309	238,620
18-Aug	2.733	3.352	3.223	1.05	0.62	0.47	0.39	0.18	0.15	TT6,TTT	289,601	278,493
19-Aug	4.230	2.722	2.747	0.13	0.11	0.10	0.03	0.04	0.04	365,493	235,154	237,326
20-Aug	4.400	2.888	2.869	0.11	0.11	0.09	0.02	0.04	0.03	380,175	249,520	247,888
21-Aug	4.424	2.911	T,89T	0.11	0.13	0.11	0.03	0.04	0.04	382,194	251,479	249,877
22-Aug	4.274	2.703	2.750	0.06	0.06	0.06	0.01	0.02	0.02	T69.ZT$	233,514	237,636
23-Aug	4.310	2.783	2.844	0.09	0.10	0.08	0.02	0.04	0.03	372,377	240,485	245,716
24-Aug	4.758	3.488	3.385	0.24	0.43	0.33	0.05	0.12	0.10	411,095	301,394	292,463
25-Aug	4.634	3.388	3.321	0.24	0.38	0.29	0.05	0.11	0.09	400,375	292,753	286,945
26-Aug	3.717	2.114	2.266	0.21	0.30	0.27	0.06	0.14	0.12	321,141	182,628	195,795
27-Aug	2.445	0,600	0,T9T	0.22	0.20	0.22	0,09	0.33	0.27	TTT,TT0	51,813	68,310
28-Aug	2.206	0.317	0.456	0.19	0.18	0.23	0.08	0.56	0.50	190,603	27,428	39,439
29-Aug	T,6T9	0.403	0.541	0.41	0.36	0.41	0.25	0.88	0.77	T0,099	34,789	46,712
30-Aug	1.756	1.276	1.485	0.06	0.30	0.28	0.03	0.23	0.19	151,697	110,267	128,277
31-Aug	1.713	1.626	T,8T9	0.05	0.13	0.11	0.03	0.08	0.06	147,976	140,445	157,140
01-Sep	1.686	1.486	1.682	0.06	0.38	0.35	0.04	0.25	0.21	145,674	128,350	145,364
02-Sep	1.523	0.607	0.798	0,06	0.20	0.22	0,0T	0.32	0.27	TTT.ST8	52,458	68,985
03-Sep	1.078	0.205	0.311	0.32	0.17	0.22	0,J0	0.84	0.72	93,146	17,724	26,889
04-Sep	1.549	0.675	0.874	0.07	0.21	0.22	0.04	0.32	0.25	133,840	58,352	75,531
05-Sep	0.849	1.237	1.411	0,T$	0.73	0.70	0.53	0.59	0.50	TT,T69	106,840	121,918
06-Sep	0.564	2.168	2.300	0.01	0.10	0.09	0.02	0.05	0.04	48,753	187,323	198,718
07-Sep	1.394	2.464	2.533	1.30	1.04	0.89	0.94	0.42	0.35	120,448	212,905	218,825
08-Sep	3.971	T,899	2.067	0.42	0.46	0.42	0.11	0.24	0.20	343,076	164,083	178,622
09-Sep	5.687	1.030	1.227	0.94	0.56	0.54	0.17	0.54	0.44	491,374	88,994	105,977
10-Sep	7.181	0.974	1.185	0.84	0,Z$	0.27	0.12	0.26	0.22	620,436	84,176	102,426
11-Sep	5.833	0.532	0.721	0.07	0.03	0.03	0.01	0.06	0.05	504,010	TT,996	62,322
12-Sep	2.904	3.330	3.108	2.18	2.09	I.IC	0.75	0.63	0.56	250,877	287,751	268,519
13-Sep	1.061	4.919	4.407	0.02	0.43	0.32	0.01	0.09	0.07	9T,6TT	424,973	380,782
14-Sep	4.378	1.556	T,608	2.34	1.56	1.38	0.53	1.00	0,86	378,218	134,449	138,893
15-Sep	6.556	0.743	0,9T6	0,69	0.23	0.24	0.11	0.32	0.26	566,395	64,214	81,755
16-Sep	5.110	0.492	0.659	0.88	0.27	0.32	0.17	0.54	0.48	441,482	42,549	56,941
17-Sep	2.133	0,0T6	0.142	0.84	0.03	0.04	0.39	0.41	0,J0	184,314	6,524	12,226
18-Sep	2.188	0.231	0.342	1.03	0.20	0.26	0.47	0.88	0.75	T89,0TT	19,938	29,560
19-Sep	0.823	2.196	2.292	1.06	1.13	0.99	1.29	0.51	0.43	71,089	189,773	198,041
20-Sep	0,00T	4.068	3.847	0.00	1.03	0.78	3.33	0.25	0.20	63	351,474	332,340
21-Sep	1.480	1.340	1.471	1.06	1.15	1.10	0.71	0.86	0.75	127,852	115,813	127,114
22-Sep	1.657	0.159	0.250	0.28	0.17	0.21	0.17	1.05	0.85	143,165	13,767	21,605
23-Sep	1.233	0.087	0.157	0,J0	0.06	0.08	0.24	0.72	0.54	106,496	7,530	13,573
24-Sep	0.523	0.072	0.137	0.27	0.00	0.00	0.52	0.00	0,00	45,173	6,206	11,798
25-Sep	T,T89	0.072	0.137	0.31	0.00	0.00	0.24	0.00	0.00	111,327	6,206	11,798
26-Sep	0.288	0.505	0.654	0.42	0.40	0.46	1.45	0.79	0.71	24,879	43,606	56,488
27-Sep	0,000	0.834	1.041	0,00	0.26	0.26	4.51	0.31	0.25	2	72,085	89,965
28-Sep	0.823	0,T96	0.530	0.73	0.35	0.42	0,89	0.88	0.79	TT.TTT	34,222	45,793
29-Sep	1.755	0.372	0.492	0.54	0.40	0.47	0.31	1.07	0.95	151,656	32,106	42,534
30-Sep	1.220	0.151	0.240	0.32	0.16	0.20	0.26	1.05	0.85	105,444	13,085	20,725
01-Oct	0.521	0.072	0.137	0.26	0.00	0.00	0.50	0,00	0.00	44,989	6,Z06	11,798
02-Oct	0.566	0.072	0.137	0.04	0.00	0.00	0.07	0.00	0.00	48,907	6,206	11,798
03-Oct	0.159	0.643	0,T9T	0.22	0.51	0.58	1.40	0.79	0.72	13,741	55,565	68,889
04-Oct	0.000	1.711	1.888	0.00	0.59	0.54	1.61	0.35	0.29	5	147,863	163,146
05-Oct	2.107	2.004	2.125	1.66	1.00	0.93	0.79	0.50	0.44	182,063	173,119	183,581
06-Oct	5.177	3.701	3.259	0.56	1.08	0.89	0.11	0.29	0.27	447,264	319,730	281,572
07-Oct	3.230	1.463	1.596	0.91	0.80	0.72	0.28	0.55	0.45	279,100	126,388	137,914
Sub-total										16,907,652	11,675,184	12,109,041

QMCD = Discharge in main canal D/S of lateral B

QLBC = Discharge in Lateral B from IIMI calibration

QLBT = Discharge in Lateral B from NIA tables.

VMCD = Volume delivered in main canal D/S of Lateral B

VLBC = Volume delivered in Lateral B from IIMI calibration

VLBT = Volume delivered in Lateral B from NIA tables.

STD = Standard deviation

CV = Coefficient of variation

Table IV.15

Daily water delivery statistics, SOA Lateral G, 05 August to 07 October 1988.

Date	Rate of Discharge									Volume of Discharge		
	Average (m3/s)			STD (m3/s)			CV			Total (m3)		
	QMCD	QLGC	QLGT	QMCD	QLGC	QLGT	QMCD	QLGC	QLGT	VMCD	VLGC	VLGT
05-Aug	NA	0.023	0.055	NA	0.06	0.15	NA	2.73	2.71	NA	I,9II	4,753
06-Aug	NA	0.219	0.505	NA	0.10	0.17	NA	0.46	0.34	NA	18,905	43,630
07-Aug	NA	0.264	0.594	NA	0.01	0.02	NA	0.05	0.04	NA	II,8II	51,292
08-Aug	NA	0.238	0.546	NA	0.03	0.05	NA	0.12	0.10	NA	20,553	II,III
09-Aug	NA	0.191	0.459	NA	0,00	0.01	NA	0.02	0.01	NA	16,487	39,653
10-Aug	NA	0.227	0.526	NA	0.04	0.07	NA	0.16	0.13	NA	19,625	45,433
11-Aug	NA	0,TT0	0.418	NA	0.04	0.07	NA	0.22	0.18	NA	14,717	36,090
12-Aug	NA	0.340	0.712	NA	0.15	0.26	NA	0,T$	0.37	NA	29,338	61,530
13-Aug	NA	0,T0T	0.653	NA	0.12	0.22	NA	0.40	0.33	NA	T6,T0T	56,388
14-Aug	NA	0.122	0,T6$	NA	0.17	0.35	NA	1.42	1.33	NA	10,538	22,933
15-Aug	NA	0.000	0.000	NA	0.00	0.00	NA	1.87	1.87	NA	0	3
16-Aug	NA	0.361	0,T06	NA	0.25	0.48	NA	0.70	0.68	NA	31,179	6T,006
17-Aug	NA	0.657	1.224	NA	0.02	0.03	NA	0.03	0.02	NA	96,T9T	105,765
18-Aug	NA	0.816	1.452	NA	0.10	0.14	NA	0.12	0.09	NA	70,507	125,426
19-Aug	NA	0.397	0,T98	NA	0.25	0.39	NA	0.63	0.50	NA	34,322	68,909
20-Aug	NA	0.218	0.509	NA	0.01	0.03	NA	0.06	0.05	NA	18,792	43,977
21-Aug	NA	0.331	0.708	NA	0.07	0.11	NA	0,T0	0.16	NA	28,560	6T,TTT
22-Aug	NA	0.196	0.460	NA	0.09	0.17	NA	0.47	0.37	NA	T6,898	T9,T96
23-Aug	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
24-Aug	1.134	0.714	1.307	0.09	0.03	0,0$	0,08	0.04	0.04	98,008	6T,6TT	112,910
25-Aug	1.407	0.744	1.348	0.12	0.09	0.13	0.08	0.12	0.10	121,540	64,252	116,503
26-Aug	1.536	0.480	0.942	0.02	0.19	0.30	0.01	0.40	0.32	132,711	41,510	81,414
27-Aug	1.339	0.233	0.534	0.11	0.07	0.13	0.08	0.30	0.25	115,666	20,146	46,099
28-Aug	0.929	0.036	0.103	0.35	0.05	0.13	0.37	1.28	1.22	80,304	3,143	8,935
29-Aug	0.358	0.090	0,T09	0.29	0.17	0.31	0.82	1.87	1.50	30,889	7,765	18,017
30-Aug	0.200	0.095	0.224	0.11	0.14	0.29	0.57	1.51	1.31	17,268	8,251	19,312
31-Aug	0.098	0,T66	0.572	0.06	0.16	0.30	0.63	0.59	0.53	8,460	22,973	49,464
01-Sep	0.056	0.140	0.321	0.03	0.15	0.31	0.49	1.08	0.95	4,804	12,063	27,707
02-Sep	0.055	0,006	0.031	0.03	0.00	0.00	0.50	0.09	0.0T	4,712	T60	2,709
03-Sep	0.315	0.005	0.023	0.30	0.00	0.01	0.94	0.45	0.45	TT,T8T	406	2,023
04-Sep	0.691	0.005	0.026	0.44	0.00	0.01	0.64	0.53	0.49	59,740	465	2,247
05-Sep	0.085	0.108	0.254	0.12	0.12	0.27	T,T6	1.16	1.07	7,348	9,302	21,931
06-Sep	0.604	0.005	0.025	0.35	0.00	0.00	0.57	0.13	0.11	52,222	418	T,TT6
07-Sep	0.655	0.004	0.019	0.30	0.00	0.01	0.47	0.47	0.45	56,560	T0T	1,624
08-Sep	0.427	0.037	0.104	0.52	0,06	0.14	1.23	T,66	1.38	36,857	3,191	8,970
09-Sep	1.512	0.421	0.827	0.40	0.23	0.41	0.26	0.55	0.50	TT0,T96	36,390	TT,T8T
10-Sep	1.459	0.681	1.247	0.25	0.25	0.36	0.17	0.36	0.29	126,078	58,867	T0T,T08
11-Sep	1.261	0.849	1.498	0,TT	0.13	0.18	0.09	0.15	0.17	T08,98T	73,396	129,413
12-Sep	1.161	0.587	1.107	0.21	0.19	0.30	0.18	0.32	0.27	100,270	50,678	95,633
13-Sep	0.812	0,TTT	0.257	0.13	0.17	0.33	0.16	1.47	1.28	70,180	9,778	22,210
14-Sep	1.531	0,0T8	0,06T	0.60	0.03	0,0T	0.39	1.57	1.16	132,270	1,544	5,409
15-Sep	2.448	0.460	0.880	0.09	0.27	0.48	0.04	0,60	0.55	211,543	39,753	76,038
16-Sep	2.018	0.483	0.953	0.21	0.12	0.19	0.10	0.24	0.20	174,352	41,696	82,356
17-Sep	1.318	0.286	0.621	0.25	0.12	0.21	0.19	0.41	0.35	113,905	24,681	53,673
18-Sep	1.240	0,T98	0.464	0.25	0,09	0.17	0.20	0.45	0.36	T0T,TTT	17,088	40,128
19-Sep	0.833	0.048	0.142	0.30	0.03	0.09	0.36	0.70	0.67	71,953	4,119	12,302
20-Sep	0.323	0.028	0,0T0	0.38	0.06	0.15	1.17	2.17	2.14	TT,880	2,391	6,035
21-Sep	0,T99	0.098	0.258	0.26	0.07	0.15	0.32	0.68	0.59	69,033	8,491	22,308
22-Sep	0.827	0.091	0.251	0.18	0.04	0,08	0.22	0.41	0.34	71,443	7,852	TT,68T
23-Sep	0.424	0.438	0.863	0.42	0.23	0.39	0.99	0.53	0.45	36,599	37,867	74,520
24-Sep	0.035	0.308	0,660	0.02	0.14	0.25	0,6T	0.46	0,TT	3,064	26,650	56,987
25-Sep	0.116	0.485	0,9Z9	0.10	0.09	0.15	0,8T	0.19	0.16	10,047	TT,9Z6	82,862
26-Sep	0,T8T	0.314	0,6TT	0.15	0.09	0.15	0.84	0.28	0.21	15,615	27,095	58,467
27-Sep	0.342	0.236	0.533	0.20	0.09	0.18	0.58	0.38	0.33	29,519	20,362	46,056
28-Sep	0,T0T	0.338	0.645	0.20	0.31	0.57	0,96	0.91	0.88	TT,88T	29,223	55,712
29-Sep	0.335	0.002	0.009	0.34	0.00	0,0T	1.00	1.02	0.99	28,944	134	761
30-Sep	0.901	0.111	0.221	0.28	0.24	0.44	0.31	T,T6	1.97	TT,86T	9,555	19,067
01-Oct	0,98T	0.002	0.013	0.34	0.00	0.00	0.35	0.23	0.22	85,269	183	1,106
02-Oct	0.184	0,000	0.000	0.11	0.00	0.00	0.60	3.05	3.05	15,886	0	3
03-Oct	0.432	0,006	0.023	0.16	0.02	0.04	0.37	2.75	1.91	37,321	688	1,972
04-Oct	0.245	0.004	0.023	0,08	0,00	0.01	0.34	0.28	0.23	TT,TT8	381	1,982
05-Oct	0.790	0.007	0.028	0.69	0.02	0.05	0.87	2.58	1.77	68,257	603	2,377
06-Oct	1.831	0.003	0,0T8	0,08	0.00	0.00	0.04	0.00	0.00	158,231	272	1,527
07-Oct	T,T66	0.216	0.467	0.23	0.16	0.34	0.15	0.75	0.73	135,310	18,701	40,335
Sub-total										3,110,931	1,284,791	2,626,968

QMCD = Discharge in main canal D/S of Lateral G

QLGC = Discharge in Lateral G from 11M1 calibration

QLGT = Discharge in Lateral G from NIA tables.

VMCD = Volume delivered in main canal D/S of Lateral G

VLGC = Volume delivered in Lateral G from 11M1 calibration

VLGT = Volume delivered in Lateral G from NIA tables.

STD = Standard deviation

CV = Coefficient of variation

NA = Data not available

Table IV.19
Intensity of operations at two diversions along Kirindi Oya Right Bank Main Canal

Location of the diversions:	GR3:DC5 (head)	GR12:BC2 (tail)
Period 6 March to 10 April 1988		
Cultivation in tract 1 (DC#5) is in stages 3, 4, and 5 (supply ends on 7 April)		
Cultivation in tract 5 (BC#2) is in stages 2 and 3		
Total number of interventions at the location: Daily mean =	1.3	4.4
Number of interventions at the regulator: Daily mean =	0.9	5.4
Number of interventions at the offtake: Daily mean =	0.5	0.8
Period 17 April to 25 April 1988		
No irrigation in tract 1 (DC#5 closed)		
Cultivation in tract 5 (BC#2) resumed on 17 April after closure of main canal		
Total number of interventions at the location: Daily mean =	1.3	3.4
Number of interventions at the regulator: Daily mean =	1.3	4.7
Number of interventions at the offtake: Daily mean =	closed	0.3
Period 26 April to 11 May 1988		
No irrigation in tract 1 (DC#5 closed)		
Cultivation in tract 5 (BC#2) is in Stage 3		
System "sealed" (no operations) from 26 April to 2 May for experimental purposes		
Total number of interventions at the location: Daily mean =	0.0	1.3
Number of interventions at the regulator: Daily mean =	0.0	1.3
Number of interventions at the offtake: Daily mean =	closed	0.4
Period from 12 May to 31 May 198t		
Start of second cultivation in tract 1 (first issue to DC#5 on 12 May)		
Cultivation in tract 5 (BC#2) is in Stages 3, 4, and 5.		
Total number of interventions at the location: Daily mean =	1.0	1.9
Number of interventions at the regulator: Daily mean =	2.0	1.8
Number of interventions at the offtake: Daily mean =	0.3	0.7

Table IV.22

Galnewa project: Issue from Kalawewa and other tanks, Yala 1988.

Date	Issues from Kalawewa LB		Galnewa Block		Mulannatuwa Tank						Kalankuttiya Tank					
	Anti. (m3/s)	Actual (m3/s)	Issue Anti. (m3/s)	Issue Actual (m3/s)	Inflow Anti. (m3/s)	Inflow Actual (m3/s)	TWL Anti. (m)	TWL Actual (m)	Issues Anti. (m3/s)	Issues Actual (m3/s)	Inflow Anti. (m3/s)	Inflow Actual (m3/s)	TWL Anti. (m)	TWL Actual (m)	Issues Anti. (m3/s)	Issues Actual (m3/s)
10-May	4.2	4.2	1.3	1.3	2.3	2.8	1.5	1.7	0	0	2.1	2.1	2.6	2.6	2.1	2.0
11-May	4.2	4.2	1.6	1.6	2.0	2.5	1.5	1.6	2.1	2.2	2.1	2.1	2.5	2.5	2.8	3.0
12-May	6.4	6.4	1.6	1.9	3.4	1.8	1.3	1.2	2.1	2.2	2.1	1.6	2.4	2.4	3.0	2.6
13-May	6.4	6.4	1.6	2.4	4.2	3.4	1.3	0.9	2.1	2.2	2.1	2.1	2.3	2.4	3.0	2.6
14-May	6.4	6.4	1.6	2.1	4.2	3.7	1.2	0.8	2.1	2.0	2.1	1.7	2.3	2.3	3.0	2.9
15-May	6.4	6.4	1.6	2.1	4.2	3.7	1.1	0.8	2.1	1.7	2.1	1.7	2.2	2.2	3.0	2.9
16-May	6.4	6.4	1.6	2.1	4.2	3.7	1.1	0.8	2.1	2.0	2.1	1.7	2.1	2.1	3.0	2.8
17-May	6.4	6.4	2.0	1.5	3.7	4.2	0.8	0.8	2.1	2.0	1.7	1.9	2.0	2.0	2.8	2.9
18-May	6.4	6.4	2.0	1.8	3.7	4.0	0.8	0.9	2.1	2.0	1.7	1.9	1.9	1.9	2.8	2.8
19-May	5.7	5.7	2.0	1.1	3.1	4.0	0.8	0.8	2.1	2.1	1.7	1.9	1.8	1.7	2.8	2.8
20-May	5.7	2.8	2.0	0	3.1	4.2	0.6	1.0	2.1	2.2	1.1	2.1	1.7	2.1	0	0.7
21-May	4.2	2.8	0	0	3.8	2.5	0.6	1.1	2.1	0.8	1.7	2.1	1.6	2.2	0	0.3
22-May	3.5	2.8	0	0	3.2	2.1	0.6	1.0	1.4	0.7	1.7	2.1	1.6	2.3	0	0.3
23-May	5.7	5.7	2.0	3.4	3.2	1.2	0.9	0.9	2.0	1.1	1.9	1.9	2.5	2.5	3.1	3.1
24-May	7.1	7.1	2.0	2.9	5.1	2.8	0.9	0.4	2.0	2.0	2.8	1.3	2.3	2.3	3.1	3.1
25-May	7.1	7.1	1.8	1.8	4.5	4.6	0.9	0.5	1.8	1.8	2.8	1.3	2.3	2.2	3.1	3.1
26-May	4.2	4.2	1.5	1.5	2.3	4.2	0.8	0.6	1.8	2.0	0.6	1.7	2.3	2.0	0.4	1.5
27-May	2.8	2.8	0	0.8	2.5	3.0	0.9	0.6	1.4	1.4	0.3	1.4	2.3	2.0	0	0.2
28-May	2.1	2.1	0	0	1.9	2.5	1.0	0.5	0.8	0.8	0.3	0.9	2.3	2.1	0	0.3
29-May	2.1	2.1	0	0	1.9	1.6	1.1	0.7	0	0	0.3	0	2.1	2.1	0	0
30-May	2.1	2.1	0	0	1.9	2.0	1.1	1.1	0	0	0.3	0	2.1	2.2	0	0
31-May	7.1	7.1	2.0	1.7	2.1	1.4	1.2	1.2	2.0	0	2.1	2.1	2.0	2.2	Ⅎ.1	2.5
01-Jun	7.1	7.1	2.0	2.9	4.4	3.4	1.0	1.2	2.0	2.2	2.8	2.2	1.9	2.0	3.1	3.2
02-Jun	4.2	3.5	1.8	3.3	2.0	4.0	1.0	0.9	1.8	2.2	2.8	2.2	1.8	2.0	3.1	3.2
03-Jun	2.5	2.5	1.5	0.9	1.3	2.3	0.9	0.8	1.8	2.0	0	0	2.0	2.0	0,4	0.3
04-Jun	2.1	2.1	0	0.5	1.9	2.3	0.8	0.7	0,8	1.8	0	0	2.0	2.1	0,[illegible]	0.4
05-Jun	2.1	2.1	0	0.4	1.9	1.4	0.9	0.9	1.4	0	0	0		2.1	0	0
06-Jun	2.1	2.1	0	0.3	1.9	1.6	1.0	1.1	0,8	0.3	0	0	2.0	2.[illegible]	0	0
07-Jun	5.7	5.7	2.0	2.2	3.1	1.6	1.1	1.3	0	0.3	1.4	1.5	2.0	2.1	3.1	0
08-Jun	5.7	5.7	2.0	2.3	3.0	2.8	1.1	1.0	2.0	2.1	2.3	2.2	1.9	2.2	Ⅎ.1	0
09-Jun	4.2	4.2	1.8	2.2	3.3	2.8	0.9	0.7	2.0	2.1	2.3	2.1	1.8	2.3	Ⅎ.1	0.5
10-Jun	2.5	2.9	1.2	0.3	1.1	3.0	0.8	0.8	1.8	2.0	0	0	2.3	2.3	0	0.Ⅎ
11-Jun	2.1	2.1	0	0	1.9	1.8	0.7	1.2	[illegible].8	0	0	0.5	2.2	2.3	0	
12-Jun	2.1	2.1	0	0	1.9	1.6	0.7	1.3	1.4	0	0	0.5	2.2	2.2	0	
13-Jun	2.1	3.8	0	0	1.9	1.2	0.7	1.3	0.8	1.6	1.1	1.4	2.2	2.1	Ⅎ.1	Ⅎ.Ⅎ
14-Jun	5.7	5.7	Z.Ǝ	2.4	2.8	1.6	0.7	1.1	0	1.4	2.3	2.3	2.0	2.0	3.1	Ǝ.Ⅎ
15-Jun	5.7	5.0	Z.Ⅎ	2.8	2.8	2.3	0.8	0.6	2.0	1.8	2.3	1.9	1.9	1.8	3.1	3.4
16-Jun	4.2	3.1	1.6	2.[illegible]	2.3	2.3	0.6	0.4	2.0	1.4	0	1.5	1.8	1.7	0.4	0,5
17-Jun	2.5	3.4	1.2	1.2	1.1	1.8	0.4	0.4	1.4	1.5	0	0	1.7	1.7	0.4	0
18-Jun	2.1	2.1	0	0	1.9	1.6	0.5	0.3	0,8	1.4	0	0	1.7	1.7	0	0
19-Jun	2.1	2.1	0	0	1.9	1.8	0.7	0.4	0	1.4	u	0	1.7	1.7	0	0
20-Jun	2.1	3.9	0	0	1.9	1.6	0.7	0.4	0	1.6	1.4	0	1.8	1.7	0	0
21-Jun	5.7	5.7	Z.Ⅎ	1.1	2.8	2.8	0.9	0.6	2.0	0	2.0	2.9	2.0	1.7	Ⅎ.1	Ⅎ.Z
22-Jun	5.7	5.7	2.3	2.5	2.8	2.5	0.8	0.5	2.1	0	2.8	2.5	2.0	1.6	L.Ⅎ	Ǝ.Ⅎ
23-Jun	5.0	6.2	2.5	1.5	2.3	2.8	0.7	0.4	1.8	1.6	2.0	2.3	1.9	1.5	3.1	3.3
24-Jun	7.1	7.1	1.2	0.4	5.2	5.0	0.3	0.3	1.8	2.0	2.1	2.1	1.3	1.4	1.0	0.9
25-Jun	7.1	7.1	0	0	6.4	5.4	0.8	0.5	2.1	2.4	1.4	1.5	1.5	1.5	0	0.2
26-Jun	7.1	5.7	0	0	5.1	5.9	1.0	0.9	2.1	2.5	1.4	1.5	1.7	1.7	0	0
27-Jun	4.2	4.2	0	0	3.8	5.5	1.1	1.1	1.4	2.6	1.4	1.7	1.9	1.9	0	0
28-Jun	4.2	Ǝ.S	2.3	0	1.6	4.0	1.0	1.3	0.8	2.0	1.4	1.7	1.8	2.0	3.3	Ⅎ.0
29-Jun	5.7	2.9	2.3	1.6	2.8	1.4	1.0	1.1	0	1.8	2.8	2.9	1.8	1.9	Ǝ.Ⅎ	Ⅎ.0
30-Jun	5.0	2.9	1.6	2.2	2.9	3.4	1.0	0.7	0	0.0	2.8	2.9	1.7	1.8	Ⅎ.Ⅎ	3.4
01-Jul	5.7	5.7	1.2	0	3.9	3.4	0.6	0.6	0	0	0	0	1.7	1.5	1.0	0,5
02-Jul	2.8	2.8	0	0	2.3	4.2	1.1	0.8	0	0	0	0	1.7	1.5	0	0,5
03-Jul	2.8	2.8	0	0	2.3	2.8	1.4	1.3	1.8	2.0	1.4	1.5	1.7	1.4	0	0.Ⅎ
04-Jul	4.2	4.3	0	0	3.8	2.8	1.1	1.2	1.8	2.0	2.1	2.1	1.9	1.5	0	0
05-Jul	4.2	Λ.Ǝ	2.3	2.2	1.6	4.2	1.1	1.1	2.3	2.[illegible]	2.1	2.1	2.1	7.7	Ǝ.Ⅎ	3.0
06-Jul	5.0	3.2	2.3	n.a	2.2	4.2	0.9	0.9	2.3	2.2	2.1	2.1	2.0	1.7	3.3	0
07-Jul	5.0	0,S	T.6	n.ə	2.9	0	0.8	1.1	1.4	0	1.4	n.a.	1.8	1.9	Ⅎ.Ⅎ	0.3
08-Jul	2.8	0	1.2	0	2.5	1.6	0.9	1.3	0	1.3	0	0.5	1.9	2.1	0	0.3
09-Jul	2.8	0	0	0	2.5	0	1.4	1.3	0	0	0	0.5	1.9	2.1	0	0.3
10-Jul	2.8	0	0	0	2.5	0	1.4	1.2	1.8	0	0, 7	0.5	2.0	2.2	0	0.3
11-Jul	5.7	0	0	0	5.1	0	1.5	1.0	1.8	0	3.3	0.5	2.3	2.2	0	0.3
12-Jul	5.7	1.4	2.3	0	2.8	0	1.5	0.9	2.3	0	1.4	0.4	2.2	2.2	3.0	0.3
13-Jul	5.0	2.9	2.3	0	2.1	0	1.4	0.7	2.3	0	1.4	0.4	2.0	2.2	0.Ⅎ	0.3
14-Jul	5.0	7.7	T.6	0	2.9	2.0	1.3	0.7	1.4	0	2.8	0.4	2.0	2.2	0.Ⅎ	0.3

n.a - not available

Table V.l

Kalankuttiya: Daily coefficients of **variation** of branch canal **water level** (**above pipe** invert of **305D3) at** DBW1, **and daily** coefficient8 of variation of discharge into distributary canal 305D3

Date (88)	Water level (m) Min.	Max.	Mean	STD	CV	Discharge (m3/s) Min.	Max.	Mean	STD	CV
09-May	1.082	1.092	1.088	0.002	0.002	0.113	0.264	0.165	0.071	0.411
10-May	1.085	1.119	1.098	0.014	0.013	0.076	0.111	0.103	0.014	0.132
11-May	1.104	1.127	1.114	0.007	0.006	0.076	0.095	0.084	0.008	0.098
12-May	1.104	1.109	1.107	0.002	0.002	0.093	0.095	0.095	0.000	0.002
13-May	1.107	1.121	1.111	0.005	0.004	0.084	0.189	0.096	0.022	0.228
14-May	1.114	1.120	1.115	0.001	0.001	0.089	0.101	0.096	0.004	0.047
15-May	1.111	1.118	1.114	0.003	0.001	0.101	0.103	0.101	0.000	0.002
16-May	1.111	1.219	1.126	0.028	0.025	0.075	0.189	0.114	0.064	0.561
17-1111	1.111	1.114	1.113	0.000	0.000	0.097	0.099	0.097	0.000	0.002
18-May	1.110	1.114	1.114	0.000	0.000	0.099	0.099	0.099	0.000	0.000
19-May	0.628	1.117	0.969	0.189	0.195	0.001	0.099	0.075	0.036	0.473
20-May	0.628	1.108	0.887	0.217	0.245	0.001	0.001	0.002	0.001	0.486
21-May	1.009	1.040	1.031	0.008	0.008	0.002	0.002	0.002	0.000	0.000
22-May	0.681	1.014	0.855	0.112	0.155	0.001	0.001	0.001	0.001	0.508
23-May	0.818	1.133	1.064	0.085	0.080	0.001	0.148	0.079	0.070	0.893
24-May	1.109	1.115	1.112	0.003	0.003	0.111	0.219	0.163	0.051	0.313
25-May	1.114	1.120	1.117	0.003	0.002	0.123	0.197	0.169	0.032	0.187
26-May	1.031	1.123	1.110	0.023	0.021	0.002	0.197	0.085	0.096	1.129
27-May	0.591	1.031	0.775	0.149	0.192	0.000	0.130	0.018	0.010	1.667
28-May	0.410	0.898	0.706	0.163	0.230	0.000	0.117	0.021	0.019	0.898
29-May	0.410	0.575	0.466	0.069	0.148	0.000	0.000	0.000	0.000	-
30-May	0.410	0.748	0.494	0.125	0.254	0.000	0.082	0.011	0.022	1.912
31-May	0.751	1.123	1.014	0.152	0.150	0.082	0.202	0.133	0.024	0.181
01-Jun	1.102	1.112	1.109	0.003	0.002	0.146	0.148	0.148	0.000	0.001
02-Jun	1.043	1.118	1.080	0.032	0.030	0.051	0.150	0.102	0.047	0.462
03-Jun	0.699	1.053	0.911	0.151	0.166	0.016	0.055	0.019	0.017	0.410
04-Jun	0.517	0.721	0.617	0.081	0.131	0.000	0.019	0.007	0.009	1.226
05-Jun	0.410	0.565	0.500	0.056	0.113	0.000	0.000	0.000	0.001	-
06-Jun	0.410	0.664	0.599	0.086	0.143	0.000	0.011	0.011	0.011	0.968
07-Jun	0.410	0.757	0.476	0.125	0.263	0.000	0.078	0.012	0.025	2.190
08-Jun	0.759	1.137	0.987	0.140	0.142	0.001	0.177	0.117	0.039	0.335
09-lun	0.981	1.041	1.023	0.021	0.020	0.117	0.130	0.124	0.005	0.048
10-Jun	0.659	0.993	0.844	0.148	0.175	0.017	0.123	0.078	0.045	0.580
11-Jun	0.659	1.079	1.003	0.119	0.118	0.001	0.00	0.007	0.002	0.267
12-Jun	1.076	1.085	1.081	0.003	0.002	0.006	0.146	0.034	0.055	1.634
13-Jun	1.076	1.123	1.104	0.016	0.015	0.003	0.146	0.091	0.069	0.757
14-Jun	1.110	1.124	1.117	0.003	0.003	0.146	0.150	0.147	0.001	0.012
15-Jun	1.113	1.120	1.116	0.001	0.001	0.073	0.208	0.148	0.014	0.094
16-Jun	0.703	1.116	1.017	0.127	0.125	0.003	0.150	0.110	0.050	0.450
17-Jun	0.677	1.032	0.825	0.152	0.184	0.004	0.121	0.045	0.038	0.847
18-Jun	0.991	1.034	1.032	0.005	0.005	0.004	0.005	0.005	0.000	0.009
19-Jun	0.754	1.033	0.991	0.080	0.080	0.004	0.091	0.017	0.026	1.491
20-Jun	0.570	0.819	0.714	0.061	0.085	0.000	0.060	0.016	0.01'	0.08
21-Jun	0.526	1.127	0.934	0.269	0.287	0.000	0.157	0.098	0.066	0.680
22-Jun	1.119	1.125	1.123	0.002	0.001	0.123	0.137	0.133	0.002	0.018
23-Jun	1.119	1.123	1.121	0.002	0.001	0.132	0.137	0.132	0.00	0.006
24-Jun	0.578	1.124	1.017	0.174	0.171	0.000	0.119	0.081	0.06	0.744
25-Jun	0.410	0.631	0.570	0.062	0.110	0.000	0.002	0.000	0.00	1.892
26-Jun	0.536	1.011	0.761	0.187	0.246	0.000	0.141	0.066	0.0611	0.906
27-Jun	0.710	1.038	0.878	0.132	0.150	0.007	0.143	0.082	0.0411	0.582
28-Jun	0.998	1.123	1.087	0.052	0.048	0.006	0.150	0.101	0.061	0.670
29-Jun	1.120	1.126	1.124	0.002	0.002	0.148	0.153	0.148	0.000	0.003
30-Jun	1.121	1.128	1.124	0 002	0.002	0.116	0.150	0 150	0.002	0.010
01-Jul	0.410	1.123	0.862	0.300	0.148	0.000	0.148	0.088	0.0611	0.766
02-Jul	0.410	0.583	0.496	0.076	0.152	0.000	0.000	0.000	0.000	-
03-Jul	0.549	0.825	0.666	0.084	0.126	0.000	0.071	0.011	0.022	1.956
04-Jul	0.612	1.006	0.157	0.161	0.215	0.000	0.005	0.002	0.00'	0.975
05-Jul	0.821	1.135	1.069	0.089	0.083	0.004	0.157	0.098	0.07	0.149
06-Jul	0.703	1.129	0.966	0.162	0.168	0.037	0.157	0.116	0.04'	0.151
07-Jul	0.903	1.016	0.996	0.049	0.049	0.004	0.117	0.040	0.05	1.276
08-Jul	1.031	1.019	1.034	0.005	0.005	0.003	0.004	0.004	0.0011	0.019
09-Jul	1.032	1.042	1.034	0.001	0.003	0.003	0.001	0.003	0.000	0.011
10-Jul	1.036	1.037	1.036	0.000	0.000	0.003	0.003	0.003	0.000	0.011
11-Jul	1.035	1.037	1.037	0.001	0.001	0.001	0.001	0.003	0.000	0.000
12-Jul	1.036	1.037	1.036	0.000	0.000	0.001	0.004	0.001	0.000	0.012
13-Jul	0.994	1.036	1.032	0.009	0.009	0.004	0.004	0.004	0.001'	0.000
14-Jul	0.788	1.059	0.988	0.075	0.076	0.004	0.004	0.004	0.000	0.000
15-Jul	1.053	1.121	1.092	0.031	0.029	0.004	0.153	0.085	0.07	0.853
16-Jul	1.116	1.126	1.122	0.001	0.002	0.153	0.153	0.153	0.000	0.000
17-Jul	1.119	1.126	1.123	0.002	0.002	0.153	0.153	0.153	0.000	0.000

Date (88)	Water level (m) Min.	Max.	Mean	STD	CV	Discharge (m3/s) Min.	Max.	Mean	STD	tv
18-Jul	1.028	1.124	1.083	0.011	0.014	0.003	0.151	0.083	0.074	0.900
19-Jul	1.028	1.038	1.031	0.001	0.001	0.001	0.003	0.001	0.000	0.072
20-Jul	1.029	1.018	1.036	0.001	0.003	0.001	0.028	0.005	0.007	1.449
21-Jul	1.029	1.036	1.030	0.002	0.002	0.003	0.028	0.024	0.009	0.382
22-Jul	0.758	1.036	1.005	0,065	0.064	0.001	0.115	0.016	0.033	2.105
23-Jul	0.653	0.751	0.686	0.025	0.037	0.015	0.011	0.016	0.015	0.413
24-Jul	0.684	1.023	0.895	0.108	0.121	0.015	0.146	0.110	0.029	0.263
25-Jul	0.657	1.135	0.979	0.215	0.220	0.017	0.157	0.114	0.062	0.541
26-Jul	1.111	1.119	1.125	0.002	0.001	0.155	0.157	0.155	0.000	0.001
27-Jul	1.120	1.121	1.122	0.001	0.001	0.146	0.157	0.152	0.006	0.038
28-Jul	1.067	1.120	1.100	0.017	0.015	0.004	0.146	0.065	0.069	1.056
29-Jul	1.027	1.088	1.073	0.022	0.020	0.003	0.004	0.004	0.000	0.011
30-Jul	0.662	1.030	0.991	0.091	0.092	0.003	0.022	0.006	0.005	0.943
31-Jul	0.621	0.865	0.722	0.085	0.117	0.000	0.029	0.016	0.010	0.651
01-Aug	0.612	0.953	0.811	0.120	0.148	0.019	0.061	0.044	0.019	0.446
02-Aug	P.626	1.126	0.963	0.220	0.229	0.001	0.146	0.091	0.060	0.623
03-Aug	1.120	1.125	1.124	0.002	0.002	0.146	0.148	0.146	0.000	0.001
04-Aug	1.120	1.125	1.122	0.001	0.001	0.148	0.148	0.148	0.000	0.000
05-Aug	1.087	1.121	1.104	0.014	0.013	0.004	0.148	0.086	0.052	0.611
06-Aug	1.019	1.092	1.063	0.029	0.028	0.004	0.101	0.010	0.014	0.488
07-Aug	1.014	1.028	1.011	0.001	0.001	0.014	0.093	0.078	0.024	0.302
08-Aug	1.021	1.019	1.028	0.001	0.001	0.035	0.018	0.038	0.000	0.006
09-Aug	0.795	1.021	0.918	0.086	0.092	0.022	0.035	0.032	0.004	0.141
10-Aug	0.795	1.132	1.013	0.155	0.153	0.022	0.162	0.109	0.066	0.602
11-Aug	0.506	1.141	0.986	0.219	0.222	0.000	0.160	0.122	0.061	0.500
12-Aug	0.410	1.041	0.722	0.294	0.407	0.000	0.007	0.001	0.001	1.042
13-Aug	1.021	1.033	1.030	0.002	0.001	0.004	0.006	0.006	0.000	0.025
14-Aug	0.646	1.021	0.821	0.162	0.198	0.004	0.117	0.034	0.039	1.145
15-Aug	0.977	1.022	1.016	0.007	0.007	0.117	0.123	0.120	0.002	0.017
16-Aug	1.022	1.039	1.027	0.006	0.005	0.057	0.123	0.103	0.031	0.299
17-Aug	1.023	1.041	1.035	0.001	0.007	0.060	0.061	0.061	0.000	0.002
18-Aug	1.023	1.041	1.030	0.007	0.001	0.060	0.060	0.060	0.000	0.000
19-Aug	0.862	1.142	1.059	0.069	0.065	0.045	0.095	0.069	0.014	0.208
20-Aug	1.111	1.142	1.137	0.001	0.003	0.085	0.101	0.092	0.006	0.070
21-Aug	1.117	1.111	1.127	0.005	0.004	0.095	0.095	0.095	0.000	0.000
22-Aug	1.118	1.128	1.122	0.004	0.001	0.007	0.095	0.051	0.043	0.818
23-Aug	1.108	1.119	1.114	0.004	0.004	0.007	0.212	0.104	0.070	0.669
24-Aug	1.029	1.108	1.081	0.028	0.016	0.001	0.208	0.060	0.078	1.292
25-Aug	0.952	1.034	1.022	0.018	0.018	0.001	0.189	0.014	0.066	1.929
26-Aug	0.867	1.020	0.904	0.046	0.050	0.055	0.155	0.116	0.027	0.231
27-Aug	1.020	1.016	1.029	0.008	0.001	0.002	0.011	0.029	0.034	1.180
28-Aug	1.015	1.041	1.036	0.001	0.001	0.001	0.002	0.002	0.000	0.046
29-Aug	1.038	1.044	1.041	0.002	0.002	0.001	0.001	0.001	0.000	0.000
30-Aug	1.044	1.045	1.044	0.000	0.000	0.001	0.001	0.001	0.000	0.026
31-Aug	1.044	1.047	1.045	0.001	0.001	0.000	0.001	0.000	0.000	0.220
01-Sep	1.044	1.047	1.046	0.001	0.001	0.000	0.001	0.001	0.000	0.290
02-Sep	1.026	1.047	1.040	0.007	0.007	0.001	0.001	0.001	0.000	0.000
03-Sep	1.040	1.047	1.046	0.002	0.002	0.001	0.052	0.008	0.017	2.081
04-Sep	1.037	1.045	1.042	0.003	0.003	0.003	0.060	0.011	0.027	0.821
05-Sep	1.035	1.037	1.036	0.001	0.001	0.055	0.060	0.058	0.001	0.036
06-Sep	0.888	1.126	1.065	0.060	0.057	0.001	0.155	0.050	0.031	0.620
07-Sep	1.111	1.116	1.113	0.002	0.002	0.103	0.107	0.104	0.001	0.010
08-Sep	1.107	1.116	1.114	0.002	0.002	0.050	0.127	0.101	0.026	0.259
09-Sep	1.028	1.121	1.091	0.038	0.034	0.080	0.093	0.090	0.005	0.017
10-Sep	1.028	1.065	1.036	0.009	0.009	0.004	0.080	0.033	0.017	1.102
11-Sep	1.040	1.040	1.040	0.000	0.000	0.001	0.004	0.004	0.000	0.021
12-Sep	1.040	1.041	1.040	0.001	0.001	0.001	0.003	0.001	0.000	0.000
13-Sep	1.039	1.043	1.042	0.001	0.001	0.001	0.001	0.003	0.000	0.075
14-Sep	1.011	1.057	1.040	0.001	0.003	0.003	0.003	0.003	0.000	0.077
15-Sep	1.039	1.041	1.040	0.001	0.001	0.001	0.001	0.001	0.000	0.000
16-Sep	1.039	1.044	1.040	0.001	0.001	0.001	0.001	0.003	0.000	0.015
17-Sep	1.034	1.044	1.042	0.003	0.003	0.001	0.003	0.003	0.000	0.000
18-Sep	1.034	1.015	1.034	0.000	0.000	0.001	0.001	0.001	0.000	0.012
19-Sep	1.035	1.037	1.016	0.001	0.001	0.001	0.003	0.003	0.000	0.000
20-Sep	1.035	1.040	1.037	0.002	0.002	0.002	0.003	0.003	0.000	0.014
21-Sep	1.027	1.051	1.046	0.008	0.008	0.002	0.107	0.064	0.048	0.738
22-Sep	1.049	1.056	1.053	0.003	0.003	0.107	0.107	0.107	0.000	0.000
23-Sep	1.049	1.077	1.063	0.013	0.012	0.107	0.113	0.107	0.001	0.005
24-Sep	1.077	1.097	1.087	0.009	0.008	0.003	0.113	0.058	0.055	0.944

Next >>

Table V.2

Kalankuttiya: Daily coefficients of variation of branch canal water level (above pipe invert of 10701) It the tail end, and daily coefficients of variation of discharge into distributary canal 10701

Date (88)	Water level (m) Min.	Max.	Mean	STD	CV	Discharge (m3/s) Min.	Max.	Mean	STD	CV
09-May	NA	NA	NA	NA	NA	0.000	0.205	0.016	0.087	1.116
10-May	NA	NA	NA	NA	NA	0.000	0.389	0.151	0.148	0.981
11-May	NA	NA	NA	NA	NA	0.090	0.154	0.246	0.090	0.165
12-May	NA	NA	NA	NA	NA	0.035	0.224	0.134	0.067	0.503
13-May	NA	NA	NA	NA	NA	0.160	0.473	0.261	0.113	0.421
14-May	0.442	0.550	0.490	0.026	0.054	0.154	0.444	0.192	0.029	0.011
15-May	0.462	0.529	0.496	0.024	0.048	0.372	0.410	0.401	0.015	0.039
16-May	0.482	0.908	0.601	0.132	0.217	0.369	0.766	0.517	0.117	0.226
17-May	0.468	0.595	0.516	0.048	0.089	0.353	0.506	0.437	0.062	0.142
18-May	0.374	0.494	0.428	0.042	0.097	0.278	0.360	0.111	0.029	0.094
19-May	0.150	0.536	0.333	0.117	0.352	0.000	0.494	0.218	0.155	0.712
20-May	0.150	0.524	0.218	0.119	0.547	0.000	0.402	0.065	0.128	1.954
21-May	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
22-May	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
23-May	0.150	0.781	0.334	0.224	0.672	0.000	0.348	0.131	0.139	1.058
24-May	0.338	0.393	0.159	0.016	0.015	0.200	0.281	0.212	0.027	0.115
25-May	0.167	0.615	0.464	0.091	0.200	0.251	0.425	0.337	0.062	0.184
26-May	0.308	1.031	0.708	0.180	0.255	0.106	0.618	0.443	0.098	0.221
27-May	0.150	0.108	0.157	0.028	0.177	0.000	0.106	0.003	0.015	4.615
28-May	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
29-May	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
30-May	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
31-May	0.150	0.608	0.100	0.156	0.521	0.000	0.295	0.106	0.110	1.040
01-Jun	0.297	0.474	0.378	0.038	0.101	0.108	0.291	0.208	0.063	0.101
02-Jun	0.150	0.516	0.329	0.141	0.429	0.000	0.431	0.187	0.157	0.843
03-Jun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
04-Jun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
05-Jun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
06-Jun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
07-Jun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
08-Jun	0.150	0.794	0.259	0.186	0.716	0.000	0.599	0.105	0.190	1.821
09-lun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
10-Jun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
11-Jun	0.150	0.276	0.159	0.011	0.195	0.000	0.081	0.005	0.017	3.639
12-Jun	0.150	0.170	0.235	0.083	0.152	0.000	0.270	0.079	0.091	1.159
13-Jun	0.150	0.469	0.266	0.112	0.421	0.000	0.389	0.116	0.119	1.020
14-Jun	0.265	0.516	0.395	0.080	0.203	0.076	0.462	0.291	0.130	0.444
15.1""	0.383	0.695	0.511	0.116	0.227	0.266	0.637	0.442	0.128	0.290
16-Jun	0.150	0.705	0.464	0.203	0.418	0.000	0.627	0.161	0.241	0.657
17-Jun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
18-Jun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
19-Jun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
20-Jun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
21-Jun	0.150	0.464	0.270	0.130	0.482	0.000	0.101	0.114	0.125	1.090
22-Jun	0.350	0.636	0.441	0.055	0.124	0.187	0.474	0.115	0.088	0.263
23-Jun	0.343	0.491	0.411	0.053	0.128	0.231	0.502	0.155	0.102	0.288
24-Jun	0.150	0.608	0.411	0.142	0.129	0.000	0.574	0.121	0.183	0.570
25-Jun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
26-lun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
27-Jun	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
28-Jun	0.150	1.105	0.310	0.202	0.650	0.000	0.725	0.177	0.192	1.083
29-lun	0.160	0.501	0.422	0.051	0.122	0.266	0.196	0.125	0.038	0.118
30-Jun	0.169	0.541	0.449	0.051	0.115	0.280	0.420	0.165	0.028	0.077
01-Jul	0.150	0.603	0.140	0.166	0.490	0.000	0.471	0.178	11.151	0.861
02-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
03-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
04-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
05-Jul	0.150	0.477	0.275	0.145	0.526	0.000	0.330	0.121	0.144	1.172
06-Jul	0.150	0.416	0.298	0.143	0.480	0.000	0.312	0.145	0.140	0.967
07-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
08-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
09-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
10-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
11-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	1.000	-
12-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.031	0.005	0.011	2.297
13-Jul	0.150	0.277	0.210	0.058	0.277	0.031	0.111	0.064	0.034	0.525
14-Jul	0.150	0.266	0.164	0.035	0.213	0.000	0.091	0.025	0.025	0.989
15-Jul	0.150	0.588	0.109	0.128	0.415	0.037	0.108	0.141	0.100	0.706
16-Jul	0.128	0.458	0.387	0.032	0.083	0.184	0.507	0.262	0.091	0.355
17-Jul	0.141	0.552	0.411	0.040	0.092	0,216	0.501	0.161	0.086	0.219

Date (88)	Water level (m) Min.	Max.	Mean	STD	CV	Discharge (m3/s) Min.	Max.	Mean	STD	CV
18-Jul	0.150	0.381	0.275	0.098	0.155	0.000	0.272	0.143	0.114	0.791
19-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
20-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
21-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
22-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
23-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
24-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
25-ful	0.150	0.621	0.272	0.116	0.499	0.000	0.457	0.149	0.160	1.074
26-Jul	0.316	0.476	0.182	0.049	0.127	0.195	0.185	0.287	0.060	0.209
27-Jul	0.108	0.594	0.198	0.059	0.1'49	0.147	0.449	0.101	0.089	0.296
28-Jul	0.150	0.632	0.413	0.101	0.251	0.000	0.491	0.314	0.127	0.405
29-Jul	0.248	0.648	0.521	0.108	0.207	0.065	0.616	0.414	0.156	0.378
30-Jul	0.150	0.248	0.153	0.016	0.102	0.000	0.061	0.006	0.014	2.402
31-Jul	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
01-Aug	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
02-Aug	0.150	0.427	0.255	0.119	0.464	0.000	0.579	0.135	0.155	1.149
03-Aug	0.110	0.422	0.360	0.024	0.066	0.178	0.322	0.254	0.048	0.188
04-Aug	0.323	0.417	0.167	0.031	0.084	0.195	0.385	0.281	0.058	0.205
05-Aug	0.150	0.540	0.176	0.101	0.269	0.000	0.533	0.288	0.143	0.496
06-Aug	0.250	0.745	0.490	0.146	0.299	0.068	0.690	0.416	0.188	0.452
07-Aug	0.150	0.250	0.186	0.048	0.256	0.000	0.067	0.024	0.030	1.257
08-Aug	0.150	0.150	0.150	0.000	0.000	0.000	0.038	0.004	0.012	2.658
09-Aug	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
10-Aug	0.150	0.451	0.250	0.114	0.456	0.000	0.326	0.128	0.149	1.167
11-Aug	0.150	0.728	0.348	0.143	0.411	0.000	0.686	0.259	0.178	0.688
12-Aug	0.150	0.150	0.150	0.000	0.000	0.000	0.036	0.002	0.007	4.458
13-Aug	0.150	0.150	0.150	0.000	0.000	0.000	0.014	0.000	0.003	******
14-Aug	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
15-Aug	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
16-Aug	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
17-Aug	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
18-Aug	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	
19-Aug	0.150	1.090	0.116	0.129	1.042	0.000	0.461	0.070	0.137	1.976
20-Aug	0.402	1.072	0.659	0.269	0.407	0.301	0.681	0.428	0.104	0.244
21-Aug	0.344	0.417	0.368	0.018	0.047	0.184	0.319	0.275	0.016	0.129
22-Aug	0.297	0.141	0.441	0.110	0.248	0.158	0.548	0.321	0.133	0.414
23-Aug	0.417	0.704	0.566	0.094	0.166	0.211	0.543	0.455	0.072	0.158
24-Aug	0.241	0.465	0.362	0.065	0.179	0.052	0.287	0.201	0.077	0.181
25-Aug	0.150	0.241	0.159	0.027	0.170	0.011	0.052	0.018	0.007	0.171
26-lug	0.150	0.150	0.150	0.000	0.000	0.028	0.011	0.011	0.001	0.026
27-Aug	0.150	0.150	0.150	0.000	0.000	0.000	0.028	0.003	0.009	2.828
28-Aug	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
29-Aug	0.150	0.323	0.199	0.069	0.345	0.000	0.164	0.046	0.066	1.410
30-Aug	0.111	0.111	0.318	0.001	0.021	0.161	0.211	0.192	0.019	0.097
31-Aug	0.289	0.319	0.302	0.010	0.033	0.139	0.211	0.174	0.025	0.146
01-Sep	0.251	0.312	0.282	0.018	0.061	0.101	0.161	0.131	0.020	0.155
02-Sep	0.150	0.257	0.203	0.053	0.263	0.000	0.104	0.051	0.050	0.975
03-Sep	0.150	0.275	0.215	0.059	0.216	0.000	0.132	0.065	0.060	0.923
04-Sep	0.150	0.271	0.241	0.046	0.189	0.000	0.133	0.090	0.042	0.466
05-Sep	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
06-Sep	0.150	0.555	0.253	0.159	0.610	0.000	0.314	0.088	0.135	1.538
07-Sep	0.108	0.555	0.398	0.090	0.225	0.186	0.366	0.248	0.011	0.133
08-Sep	0.308	0.766	0.506	0.180	0.356	0.186	0.421	0.298	0.091	0.312
09-Sep	0.238	1.147	0.657	0.217	0.361	0.059	0.809	0.415	0.212	0.512
10-Sep	0.150	0.239	0.153	0.016	0.106	0.000	0.062	0.023	0.026	1.144
11-Sep	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
12-Sep	0.150	0.100	0.221	0.068	0.305	0.000	0.172	0.082	0.075	0.906
13-Sep	0.269	0.300	0.289	0.009	0.010	0.128	0.184	0.161	0.016	0.099
14-Sep	0.269	0.295	0.278	0.009	0.032	0.126	0.178	0.149	0.018	0.121
15-Sep	0.272	0.283	0.279	0.004	0.016	0.135	0.158	0.150	0.008	0.052
16-Sep	0.270	0.282	0.278	0.005	0.017	0.130	0.151	0.146	0.008	0.057
17-Sep	0.249	0.210	0.267	0.005	0.017	0.083	0.114	0.125	0.011	0.085
18-Sep	0.150	0.249	0.156	0.023	0.147	0.000	0.083	0.019	0.023	1.205
19-Stv	0.150	0.150	0.150	0.000	0.000	0.000	0.000	0.000	0.000	-
20-Sep	0.150	0.219	0.157	0.024	0.151	0.000	0.062	0.007	0.018	2.411
21-Sep	0.150	0,267	0.197	0.054	0.276	0.000	0.121	0.050	0.047	0.930
22-Sep	0.150	0.104	0,219	0.053	0.220	0.000	0.189	0.091	0.051	0.579
23-Sep	0.150	0.122	0.163	0.044	0.268	0.000	0.118	0.017	0.052	3.060
24-Sep	0.310	0.479	0.171	0.071	0.189	0.200	0.195	0.285	0.081	0.284

NA = not Available

Table V.3

Kalsnkuttiya: Comparison of coefficients of variation of branch canal water level at DBW1 and at the tail end during rotational periods of water issue

Rotation	Water level at DBW1 (m) (above pipe invert of 30503)					Water level at tail end (m) (above pipe invert of 307D3)					Ratio of CVs
	Min.	Max.	Mean	STD	CV	Min.	Max.	Mean	STD	CV	(Tail/DBW1)
LP	1.082	1.219	1.110	0.014	0.013	NA	NA	NA	NA	NA	NA
R1	1.109	1.120	1.115	0.003	0.003	0.338	1.031	0.513	0.186	0.362	123.4
R2	1.043	1.123	1.092	0.029	0.026	0.291	0.608	0.413	0.060	0.145	5.5
R3	1.092	1.124	1.116	0.004	0.003	0.265	0.705	0.480	0.126	0.263	82.7
R4	1.116	1.127	1.122	0.002	0.002	0.343	0.636	0.442	0.068	0.155	82.0
R5	1.112	1.128	1.123	0.003	0.002	0.334	1.105	0.446	0.095	0.214	89.1
R6	1.119	1.135	1.129	0.003	0.002	0.367'	0.477	0.442	0.035	0.079	35.4
R7	1.116	1.126	1.121	0.003	0.003	0.328	0.588	0.403	0.051	0.126	50.0
R8	1.087	1.135	1.123	0.004	0.004	0.150	0.648	0.431	0.095	0.220	60.0
R9	1.114	1.126	1.123	0.002	0.002	0.150	0.745	0.403	0.099	0.245	124.1
R10	1.116	1.141	1.126	0.005	0.004	0.337	0.728	0.398	0.092	0.231	55.2
R11	1.117	1.142	1.131	0.008	0.007	0.297	1.090	0.520	0.198	0.380	53.8
R12	'1.107	1.121	1.114	0.003	0.002	0.308	1.147	0.534	0.195	0.365	154.0
R13	1.049	1.089	1.061	0.012	0.011	0.150	0.519	0.291	0.121	0.415	31.4

NA - Not Available

Table V.4

Kalankuttiya: Comparison of coefficients of variation of discharge into distributary canals 30503 and 30703 during rotational periods of water issue

Rotation	Discharge in 305 03 (m3/s) Min.	Max.	Mean	STD	CV	Discharge in 307 03 (m3/s) Min.	Max.	Mean	STD	CV	Ratio of CVs (307D3/305D3)
LP	0.075	0.389	0.105	0.037	0.355	NA	NA	NA	NA	NA	NA
R1	0.109	0.219	0.186	0.039	0.235	0.019	0.193	0.131	0.024	0.179	0.8
R2	0.053	0.150	0.121	0.042	0.351	0.090	0.173	0.136	0.019	0.142	0.4
R3	0.073	0.208	0.147	0.000	0.056	0.067	0.184	0.135	0.023	0.111	3.0
R4	0.123	0.153	0.135	0.005	0.035	0.093	0.179	0.144	0.016	0.114	3.2
R5	0.146	0.153	0.149	0.001	0.009	0.000	0.115	0.139	0.021	0.152	16.9
R6	0.153	0.157	0.156	0.001	0.008	0.125	0.153	0.148	0.006	0.039	5.0
R7	0.150	0.153	0.152	0.001	0.006	0.128	0.183	0.150	0.012	0.078	13.2
R8	0.146	0.157	0.153	0.005	0.031	0.004	0.193	0.145	0.033	0.227	7.4
R9	0.141	0.148	0.146	0.003	0.018	0.008	0.202	0.149	0.050	0.336	18.9
R10	0.150	0.162	0.160	0.003	0.020	0.064	0.238	0.113	0.028	0.162	8.0
R11	0.082	0.101	0.092	0.006	0.060	0.090	0.235	0.188	0.023	0.124	2.1
R12	0.050	0.227	0.101	0.017	0.165	0.139	0.268	0.197	0.037	0.186	1.1
R13	0.101	0.113	0.107	0.004	0.033	0.002	0.161	0.076	0.058	0.761	23.2

NA - Not Available

Table V.5

Kirindi Oya Right Bank Main Canal: Daily coefficients of variation of main canal water level (above pipe of DC5) at GR3:DC5 location and daily coefficients of variation of discharge into distributary canal DC5

Date (88)	Water level (m) Min.	Max.	Mean	STD	CV	Discharge (m3/s) Min.	Max.	Mean	STD	CV	No. of gate operations DC5	GR3
06-Mar	0.653	0.817	0.735	0.036	0.049						NA	NA
07-Mar	0.445	0.829	0.714	0.107	0.150						NA	NA
08-Mar	0.722	0.835	0.748	0.024	0.032						NA	NA
09-Mar	0.739	0.758	0.747	0.007	0.010						NA	NA
10-Mar	0.738	0.754	0.747	0.005	0.006						NA	NA
11-Mar	0.746	0.785	0.760	0.016	0.020						NA	NA
12-Mar	0.785	0.802	0.791	0.004	0.006		No flow in DC5				NA	NA
13-Mar	0.605	0.927	0.808	0.060	0.074						NA	NA
14-Mar	0.738	0.903	0.803	0.070	0.087						NA	NA
15-Mar	0.736	0.820	0.781	0.030	0.038						NA	NA
16-Mar	0.746	0.839	0.783	0.035	0.045						1	1
17-Mar	0.697	0.789	0.748	0.021	0.028						0	1
18-Mar	0.646	0.701	0.676	0.022	0.033						0	0
19-Mar	0.546	0.709	0.650	0.056	0.086						0	0
20-Mar	0.702	0.809	0.742	0.041	0.055	0.315	0.386	0.342	0.027	0.078	1	0
	-0.040	0.809	0.683	0.185	0.271		No flow in DC5				0	1
	-0.350	0.709	0.259	0.453	1.746						0	1
	0.601	0.794	0.705	0.055	0.077	0.000	0.119	0.001	0.010	11.958	1	1
	0.583	0.930	0.726	0.098	0.135	0.000	0.435	0.242	0.169	0.697	2	1
25-Mar	0.638	0.755	0.721	0.036	0.051	0.259	0.348	0.321	0.025	0.078	1	3
26-Mar	0.625	0.760	0.706	0.034	0.048	0.249	0.348	0.311	0.025	0.079	0	1
27-Mar	0.620	0.883	0.741	0.085	0.115	0.104	0.414	0.242	0.109	0.449	0	2
28-Mar	0.781	0.793	0.788	0.003	0.004	0.104	0.106	0.105	0.001	0.005	1	3
29-Mar	0.724	0.796	0.759	0.026	0.034	0.105	0.379	0.235	0.103	0.437	0	0
30-Mar	0.608	0.734	0.659	0.053	0.081	0.220	0.311	0.258	0.037	0.144	1	0
31-Mar	0.618	0.761	0.693	0.058	0.084	0.000	0.286	0.089	0.113	1.274	0	0
01-Apr	0.680	0.750	0.723	0.022	0.030	0.000	0.228	0.049	0.091	1.835	1	0
02-Apr	0.668	0.686	0.677	0.003	0.005	0.204	0.216	0.210	0.002	0.011	1	0
03-Apr	0.677	0.767	0.720	0.034	0.048	0.058	0.247	0.157	0.066	0.422	0	0
04-Apr	0.737	0.835	0.785	0.030	0.038	0.000	0.061	0.028	0.029	1.043	2	0
05-Apr	0.807	0.823	0.816	0.005	0.006	0.000	0.000	0.000	0.000	-	1	0
06-Apr	0.609	0.820	0.700	0.092	0.131	0.000	0.190	0.095	0.064	0.676	0	0
07-Apr	0.589	0.812	0.665	0.079	0.119	0.000	0.200	0.100	0.056	0.557	1	1
08-Apr	0.679	0.826	0.816	0.012	0.015						1	0
09-Apr	0.776	0.829	0.804	0.020	0.025						0	0
10-Apr	0.028	0.815	0.534	0.290	0.544						0	0
11-Apr	-0.150	0.028	-0.021	0.048	-2.288						0	1
12-Apr	-0.187	0.054	-0.126	0.061	-0.481						0	0
13-Apr	-0.253	-0.192	-0.240	0.012	-0.049						0	0
14-Apr	-0.240	-0.183	-0.227	0.016	-0.072						0	0
15-Apr	-0.183	-0.162	-0.169	0.007	-0.041						0	0
16-Apr	-0.162	-0.157	-0.159	0.002	-0.016						0	0
17-Apr	-0.158	0.840	0.152	0.343	2.265						0	0
18-Apr	0.311	0.872	0.685	0.200	0.291						0	0
19-Apr	0.830	0.887	0.854	0.020	0.023						0	0
20-Apr	0.561	0.855	0.748	0.098	0.131						0	2
21-Apr	0.704	0.790	0.742	0.034	0.046						0	1
22-Apr	0.701	0.755	0.717	0.008	0.011						0	1
23-Apr	0.711	0.759	0.727	0.012	0.016						0	0
24-Apr	0.715	0.729	0.722	0.004	0.005						0	0
25-Apr	0.726	0.746	0.734	0.005	0.007		No flow in DC5				0	0
26-Apr	0.691	0.881	0.763	0.049	0.064						0	0
27-Apr	0.745	0.769	0.754	0.006	0.008						0	0
28-Apr	0.736	0.797	0.759	0.014	0.019						0	0
29-Apr	0.754	0.773	0.762	0.006	0.008						0	0
30-Apr	0.749	0.779	0.762	0.011	0.015						0	0
01-May	0.753	0.782	0.766	0.008	0.010						0	0
02-May	0.767	0.956	0.809	0.053	0.066						0	0
03-May	0.765	0.786	0.772	0.007	0.008						0	0
04-May	0.773	0.794	0.781	0.006	0.008						0	0
05-May	0.413	0.797	0.706	0.133	0.188						0	0
06-May	0.393	0.413	0.401	0.004	0.009						0	0
07-May	0.395	0.407	0.399	0.003	0.007						0	0
08-May	0.397	0.411	0.403	0.004	0.010						0	0
09-May	0.405	0.424	0.413	0.006	0.013						0	0
10-May	0.415	0.446	0.429	0.011	0.026						0	0
11-May	0.442	0.563	0.477	0.046	0.095						0	0
12-May	0.563	0.743	0.661	0.058	0.088	0.000	0.387	0.168	0.147	0.873	3	1
13-May	0.716	0.822	0.763	0.036	0.047	0.047	0.384	0.211	0.136	0.644	2	0
14-May	0.715	0.767	0.744	0.019	0.025	0.308	0.349	0.328	0.012	0.038	0	1
15-May	0.686	0.769	0.730	0.035	0.048	0.287	0.346	0.317	0.022	0.070	0	0
16-May	0.686	0.861	0.771	0.058	0.075	0.291	0.386	0.339	0.031	0.092	0	4
17-May	0.791	0.986	0.843	0.047	0.055	0.344	0.438	0.375	0.022	0.059	0	3
18-May	0.721	0.926	0.849	0.078	0.092	0.309	0.423	0.379	0.040	0.107	0	2
19-May	0.751	0.914	0.832	0.054	0.065	0.328	0.408	0.367	0.025	0.067	0	3
20-May	0.811	0.851	0.837	0.008	0.010	0.352	0.377	0.368	0.004	0.012	0	0
21-May	0.739	0.846	0.819	0.033	0.041	0.324	0.375	0.361	0.016	0.044	0	0
22-May	0.739	0.910	0.848	0.073	0.086	0.324	0.414	0.379	0.037	0.097	0	1
23-May	0.880	0.909	0.898	0.011	0.012	0.397	0.414	0.405	0.005	0.013	0	1
24-May	0.879	0.897	0.884	0.004	0.004	0.392	0.405	0.398	0.003	0.007	0	0
25-May	0.892	0.908	0.898	0.006	0.006	0.395	0.414	0.405	0.004	0.009	0	0
26-May	0.905	0.913	0.909	0.003	0.003	0.408	0.424	0.417	0.003	0.008	0	1
27-May	0.906	0.917	0.911	0.004	0.004	0.407	0.426	0.417	0.005	0.012	0	0
28-May	0.733	0.912	0.875	0.058	0.067	0.332	0.422	0.401	0.027	0.068	0	1
29-May	0.717	0.832	0.787	0.042	0.053	0.320	0.389	0.363	0.025	0.069	0	0
30-May	0.824	0.830	0.828	0.003	0.003	0.373	0.389	0.381	0.005	0.013	0	1
31-May	0.825	0.836	0.828	0.003	0.004	0.375	0.385	0.381	0.003	0.007	0	0
01-Jun	0.826	0.836	0.833	0.003	0.004	0.377	0.388	0.383	0.003	0.008	0	1
02-Jun	0.826	0.839	0.834	0.002	0.002	0.378	0.390	0.384	0.002	0.006	0	0
03-Jun	0.816	0.839	0.828	0.010	0.013	0.372	0.391	0.381	0.005	0.014	0	0
04-Jun	0.817	0.829	0.822	0.004	0.005	0.371	0.386	0.379	0.003	0.009	0	0
05-Jun	0.824	0.836	0.826	0.003	0.003	0.379	0.389	0.382	0.002	0.006	0	0
06-Jun	0.584	0.832	0.713	0.105	0.147	NA	NA	NA	NA	NA	0	0
07-Jun	0.405	0.825	0.658	0.096	0.145	NA	NA	NA	NA	NA	0	2
08-Jun	0.815	0.830	0.821	0.005	0.006	0.376	0.389	0.382	0.003	0.008	0	0
09-Jun	0.804	0.817	0.811	0.005	0.006	0.371	0.382	0.378	0.003	0.008	0	0
10-Jun	0.810	0.827	0.816	0.006	0.007	0.375	0.392	0.383	0.005	0.013	0	0
11-Jun	0.567	0.943	0.803	0.085	0.105	NA	NA	NA	NA	NA	0	3
12-Jun	0.433	0.889	0.755	0.148	0.197	NA	NA	NA	NA	NA	6	1
13-Jun	0.839	0.860	0.848	0.008	0.010	0.389	0.406	0.398	0.005	0.012	1	0
14-Jun	0.846	0.861	0.851	0.007	0.008	0.396	0.408	0.402	0.003	0.008	0	0
15-Jun	0.853	0.859	0.858	0.001	0.001	0.399	0.408	0.404	0.001	0.004	0	0
16-Jun	0.626	0.858	0.794	0.091	0.115	0.249	0.405	0.364	0.060	0.165	0	1
17-Jun	0.649	0.832	0.762	0.080	0.105	0.269	0.393	0.346	0.053	0.154	0	0
18-Jun	0.832	0.837	0.832	0.001	0.001	0.388	0.395	0.392	0.001	0.003	0	0
19-Jun	0.832	0.838	0.835	0.002	0.002	0.390	0.397	0.394	0.002	0.005	0	0
20-Jun	0.829	0.853	0.836	0.006	0.007	0.387	0.403	0.394	0.004	0.009	0	0
21-Jun	0.841	0.853	0.848	0.005	0.005	0.392	0.406	0.402	0.003	0.007	0	0
22-Jun	0.851	0.853	0.851	0.000	0.000	0.397	0.404	0.401	0.002	0.005	0	0
23-Jun	0.849	0.858	0.854	0.004	0.004	0.396	0.406	0.400	0.002	0.006	0	0
24-Jun	0.839	0.853	0.850	0.004	0.004	0.395	0.405	0.401	0.002	0.005	0	0
25-Jun	0.834	0.839	0.836	0.002	0.003	0.382	0.399	0.390	0.005	0.013	0	0
26-Jun	0.795	0.838	0.815	0.017	0.021	0.365	0.390	0.377	0.008	0.021	0	0
27-Jun	0.798	0.808	0.801	0.003	0.004	0.361	0.370	0.367	0.003	0.007	0	0
28-Jun	0.808	0.865	0.831	0.020	0.024	0.185	0.390	0.261	0.085	0.326	5	0
										Total	32	48

NA - Not Available

Table V.6

Kirindi Oya Right Bank Main Canal: Daily coefficients of variation of main canal water level (above pipe invert of BC2) at GR12:BC2 location and daily coefficients of variation of discharge into BC2

	Water level (m)					Discharge (m3/s)					No. of gate operations	
Date (88)	Min.	Max.	Mean	STD	CV	Min.	Max.	Mean	STD	CV	B	GR12
06-Mar	1.049	1.357	1.192	0.079	0.066	NA	NA	NA	NA	NA		NA
07-Mar	1.058	1.347	1.164	0.062	0.053	NA	NA	NA	NA	NA		NA
08-Mar	1.072	1.344	1.211	0.065	0.053	NA	NA	NA	NA	NA		NA
09-Mar	1.138	1.399	1.263	0.067	0.053	NA	NA	NA	NA	NA		NA
10-Mar	1.192	1.378	1.293	0.064	0.049	NA	NA	NA	NA	NA		NA
11-Mar	1.125	1.357	1.266	0.071	0.056	NA	NA	NA	NA	NA		NA
11-Mar	1.178	1.329	1.254	0.040	0.032	NA	NA	NA	NA	NA		NA
13-Mar	1.205	1.405	1.295	0.068	0.052	NA	NA	NA	NA	NA		NA
14-Mar	1.083	1.396	1.242	0.079	0.064	NA	NA	NA	NA	NA		NA
15-Mar	1.147	1.302	1.231	0.046	0.038	NA	NA	NA	NA	NA		NA
16-Mar	1.188	1.272	1.217	0.028	0.023	NA	NA	NA	NA	NA		NA
17-Mar	1.176	1.290	1.262	0.027	0.021	NA	NA	NA	NA	NA		NA
18-Mar	1.158	1.316	1.243	0.038	0.031	NA	NA	NA	NA	NA		811
19-Mar	1.201	1.309	1.249	0.031	0.025	NA	NA	NA	NA	NA		4
20-Mar	0.983	1.375	1.199	0.118	0.098	0.323	0.818	0.649	0.168	0.260		5
21-Mar	1.214	1.403	1.265	0.045	0.036	0.523	0.886	0.660	0.091	0.139		6
12-11„	1.023	1.499	1.202	0.135	0.112	0.285	0.706	0.480	0.137	0.286		6
23-Mar	1.263	1.447	1.411	0.042	0.030	0.614	1.033	0.903	0.136	0.151		5
24-Mar	1.153	1.441	1.289	0.101	0.078	0.658	1.012	0.843	0.119	0.141		5
25-Wir	1.153	1.293	1.196	0.040	0.034	0.615	0.871	0.727	0.069	0.095		5
26-Mar	1.066	1.343	1.218	0.084	0.069	0.487	0.933	0.752	0.131	0.174		1
27-Mar	1.235	1.308	1.265	0.018	0.014	0.796	0.903	0.846	0.026	0.031		1
28-Mar	1.130	1.444	1.343	0.071	0.053	0.618	1.506	1.110	0.280	0.252		5
29-Mar	1.153	1.426	1.330	0.078	0.059	1.018	1.421	1.306	0.102	0.078		10
30-Mar	1.191	1.423	1.296	0.082	0.064	0.900	1.482	1.064	0.122	0.115		4
31-Mar	1.192	1.353	1.269	0.039	0.030	0.900	1.098	1.000	0.043	0.043		4
01-Apr	1.207	1.367	1.287	0.035	0.027	0.919	1.177	1.033	0.057	0.055		6
02-Apr	1.216	1.331	1.255	0.025	0.020	0.933	1.119	0.997	0.038	0.038		1
03-Apr	1.216	1.323	1.250	0.029	0.024	0.944	1.086	0.987	0.040	0.041		5
04-Apr	1.232	1.305	1.265	0.023	0.018	0.961	1.071	1.009	0.031	0.031		6
05-Apr	1.239	1.310	1.280	0.022	0.017	0.978	1.074	1.027	0.029	0.028		2
06-Rvr	1.147	1.316	1.254	0.045	0.036	0.820	1.314	0.989	0.070	0.071		3
07-Apr	1.147	1.316	1.230	0.050	0.040	0.824	1.099	0.962	0.073	0.076		5
08-Apr	1.235	1.300	1.272	0.020	0.016	0.968	1.140	1.021	0.030	0.029		0
09-Apr	1.240	1.289	1.278	0.014	0.011	0.974	1.049	1.028	0.019	0.019		0
10-Apr	1.195	1.362	1.308	0.046	0.035	0.897	1.134	1.066	0.061	0.057		3
11-Apr	0.955	1.295	1.118	0.118	0.106	0.474	1.056	0.755	0.210	0.279		0
12-Apr	0.796	0.983	0.897	0.061	0.068	0.000	0.526	0.216	0.248	1.151		0
13-Apr	0.659	0.983	0.891	0.091	0.102	0.000	0.514	0.227	0.250	1.103		0
14-Apr	0.431	0.653	0.475	0.058	0.123	0.000	0.000	0.000	0.000	-		0
15-Apr	0.431	0.530	0.461	0.032	0.070	0.000	0.000	0.000	0.000	-		0
16-Apr	0.530	0.997	0.792	0.205	0.259	0.000	0.545	0.242	0.259	1.073		1
17-Apr	0.616	1.025	0.878	0.146	0.166	0.000	0.557	0.285	0.262	0.921		3
18-Apr	0.908	1.081	0.993	0.061	0.061	0.000	0.670	0.398	0.276	0.694		0
19-Apr	0.908	1.421	1.206	0.171	0.142	0.000	1.416	0.866	0.397	0.458		9
20-Apr	1.241	1.419	1.350	0.045	0.033	0.968	1.268	1.157	0.057	0.049		4
21-Apr	1.136	1.364	1.281	0.043	0.033	0.792	1.237	1.087	0.068	0.063		7
22-Apr	1.217	1.305	1.261	0.034	0.027	1.001	1.148	1.080	0.058	0.053		2
23-Apr	1.281	1.305	1.293	0.009	0.007	1.105	1.148	1.129	0.016	0.014	0	1
24-Apr	1.260	1.371	1.290	0.016	0.012	1.068	1.674	1.139	0.069	0.061	0	1
25-Apr	1.264	1.419	1.324	0.057	0.043	1.105	1.314	1.187	0.082	0.069	0	3
26-Apr	1.395	1.427	1.411	0.012	0.008	1.281	1.378	1.322	0.031	0.023	0	0
27-Apr	1.411	1.477	1.429	0.019	0.013	1.148	1.261	1.177	0.021	0.018	0	0
28-Apr	1.423	1.560	1.451	0.042	0.029	1.163	1.279	1.207	0.027	0.023	0	0
29-Apr	1.437	1.475	1.445	0.009	0.006	1.180	1.229	1.197	0.010	0.008	0	0
30-Apr	1.438	1.448	1.443	0.005	0.003	1.177	1.218	1.200	0.007	0.006	0	0
01-May	1.441	1.452	1.446	0.004	0.003	1.166	1.215	1.190	0.012	0.010	0	0
02-May	1.448	1.490	1.465	0.016	0.011	1.174	1.221	1.192	0.015	0.012	0	0
01-Hay	1.464	1.469	1.468	0.002	0.001	1.174	1.229	1.200	0.011	0.009	0	0
04-May	1.449	1.465	1.457	0.006	0.004	1.163	1.207	1.186	0.011	0.010	0	0
05-May	1.266	1.475	1.431	0.063	0.044	0.899	1.191	1.132	0.089	0.078	2	2
06-May	1.176	1.419	1.272	0.074	0.058	0.802	1.143	0.941	0.098	0.104	1	4
07-May	1.209	1.340	1.277	0.032	0.025	0.853	1.028	0.948	0.047	0.049	0	1
08-May	1.181	1.338	1.286	0.021	0.016	0.056	0.983	0.379	0.403	1.062	2	3
09-May	1.257	1.365	1.281	0.022	0.017	0.067	0.862	0.330	0.334	1.012	1	3
10-May	1.216	1.388	1.283	0.068	0.053	0.719	0.882	0.794	0.053	0.067	1	3
11-May	1.164	1.281	1.257	0.030	0.024	0.666	0.837	0.794	0.041	0.051	0	1
12-May	1.158	1.354	1.250	0.055	0.044	0.649	0.916	0.780	0.075	0.096	0	3
13-May	1.178	1.258	1.222	0.023	0.019	0.691	0.797	0.753	0.030	0.040	0	0
14-May	1.162	1.327	1.221	0.050	0.041	0.661	0.904	0.754	0.069	0.092	0	2
15-May	1.218	1.423	1.308	0.049	0.038	0.744	0.997	0.862	0.059	0.069	0	6
16-May	1.223	1.282	1.255	0.015	0.012	0.786	0.935	0.864	0.039	0.045	1	1
17-May	1.033	1.317	1.210	0.083	0.068	0.498	0.963	0.806	0.142	0.176	0	4
18-May	1.214	1.429	1.341	0.040	0.030	0.789	1.135	0.987	0.064	0.065	1	4
19-1111	1.412	1.469	1.453	0.017	0.012	1.019	1.173	1.095	0.043	0.039	1	0
20-May	1.422	1.465	1.440	0.013	0.009	1.001	1.070	1.035	0.018	0.017	1	0
21-May	1.438	1.474	1.459	0.014	0.010	1.011	1.154	1.100	0.056	0.051	0	1
22-May	1.395	1.474	1.452	0.025	0.017	0.834	1.158	0.979	0.136	0.139	1	0
23-May	1.395	1.429	1.412	0.013	0.009	0.823	0.849	0.836	0.005	0.006	1	1
24-May	1.373	1.427	1.412	0.014	0.010	0.788	0.848	0.825	0.013	0.016	0	0
25-May	1.266	1.381	1.345	0.031	0.023	0.565	0.798	0.648	0.090	0.138	2	2
26-May	1.304	1.369	1.362	0.013	0.010	0.566	0.703	0.649	0.055	0.085	1	0
27-May	1.277	1.315	1.301	0.015	0.012	0.632	0.675	0.657	0.013	0.019	0	0
28-1111	1.302	1.319	1.316	0.004	0.003	0.653	0.675	0.664	0.004	0.006	0	1
29-May	1.175	1.302	1.263	0.028	0.022	0.415	0.658	0.554	0.080	0.145	1	2
30-May	1.158	1.320	1.277	0.045	0.035	0.398	0.532	0.499	0.036	0.072	0	1
31-May	1.146	1.319	1.258	0.059	0.047	0.423	0.574	0.503	0.041	0.082	0	1
01-Jun	0.888	1.324	1.026	0.132	0.129	0.000	0.580	0.228	0.208	0.911	0	1
02-Jun	1.197	1.404	1.316	0.060	0.045	0.290	0.602	0.512	0.092	0.180	2	4
03-Jun	1.212	1.299	1.273	0.023	0.018	0.431	0.558	0.512	0.046	0.089	1	1
04-Jun	0.954	1.212	1.080	0.095	0.088	0.179	0.431	0.306	0.093	0.302	0	2
05-Jun	1.167	1.309	1.240	0.041	0.033	0.000	0.926	0.564	0.172	0.305	8	6
06-Iun	1.120	1.299	1.234	0.057	0.047	0.018	0.549	0.278	0.248	0.893	3	3
07-Jun	1.034	1.325	1.209	0.103	0.085	0.015	0.121	0.083	0.043	0.522	1	2
08-Jun	0.658	1.257	0.992	0.207	0.209	0.000	0.183	0.066	0.062	0.934	1	0
09-Jun	0.526	0.973	0.785	0.172	0.219	0.000	0.095	0.033	0.043	1.313	0	1
10-Jun	0.937	0.973	0.952	0.013	0.014	0.074	0.092	0.082	0.006	0.074	0	0
11-Jun	0.937	1.265	1.024	0.120	0.118	0.074	0.211	0.113	0.051	0.451	0	1
12-Jun	1.017	1.432	1.238	0.138	0.112	0.025	0.274	0.168	0.080	0.478	1	3
13-Jun	0.792	1.437	1.197	0.235	0.197	0.000	0.080	0.048	0.034	0.712	2	2
14-Jun	1.254	1.338	1.297	0.018	0.014	0.064	0.072	0.068	0.002	0.024	NA	NA
										Total	53	192

NA = Not available

Table V.8

Rajangana: Daily coefficients of variation of water level (above sill of baffle distributor) and discharge in the pilot distributary canal

oate (88)	Water level U/S of baffle distributor (m)					Discharge (m3/s)				
	Min.	Max.	Mean	STO	CV	Min.	Max.	Mean	STD	CV
06-Jul	0.308	0.313	0.309	C.002	0.007	0.260	0.269	0.260	0.001	0.003
07-Jul	0.306	0.312	0.311	C.002	0.005	0.269	0.274	0.269	0.000	0.001
08-Jul	0.311	0.313	0.313	C.001	0.002	0.274	0.303	0.285	0.014	0.048
09-Jul	0.306	0.311	0.308	0.002	0.008	0.260	0.288	0.203	0.011	0.039
10-Jul	0.305	0.307	0.305	0.001	0.002	0.204	0.274	0.273	0.001	0.003
11-Jul	0.302	0.307	0.305	C.002	0.008	0.264	0.204	0.264	0.000	0.000
12-Jul	0.305	0.306	0.305	C.000	0.000	0.230	0.264	0.263	0.005	0.018
13-Jul	0.304	0.306	0.306	0.000	0.001	0.233	0.288	0.262	0.011	0.040
14-Jul	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
15-Jul	•NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
16-Jul	0.282	0.284	0.282	0.000	0.001	0.251	0.283	0.257	0.010	0.039
17-Jul	0.283	0.204	0.284	0.000	0.000	0.284	0.288	0.269	0.009	0.035
18-Jul	0.283	0.288	0.284	0.002	0.005	0.270	0.278	0.278	0.000	0.000
19-Jul	0.272	0.207	0.284	0.006	0.020	0.251	0.278	0.269	0.009	0.034
20-Jul	0.272	0.289	0.281	0.006	0.023	0.251	0.270	0.268	0.012	0.045
21-Jul	0.284	0.289	0.287	0.002	0.009	0.274	0.278	0.278	0.000	0.001
22-Jul	0.283	0.288	0.287	0.002	0.000	0.264	0.274	0.273	0.001	0.003
23-Jul	0.287	0.325	0.311	0.017	0.053	0.202	0.274	0.234	0.022	0.092
24-Jul	0.257	0.324	0.313	0.021	0.068	0.198	0.200	0.228	0.030	0.134
25-Jul	0.271	0.320	0.303	0.021	0.069	0.210	0.274	0.237	0.024	0.103
26-Jul	0.315	0.320	0.318	0.002	0.008	0.221	0.246	0.228	0.011	0.049
27-Jul	0.314	0.320	0.318	0.003	0.008	0.238	0.246	0.246	0.001	0.003
28-Jul	0.316	0.322	0.317	0.002	0.007	0.217	0.230	0.231	0.009	0.041
29-Jul	0.319	0.321	0.320	0.001	0.003	0.213	0.221	0.221	0.001	0.00s
30-Jul	0.315	0.321	0.320	0.003	0.008	0.213	0.233	0.221	0.010	0.044
31-Jul	0.275	0.315	0.305	0.015	0.050	0.225	0.288	0.238	0.025	0.106
01-Aug	0.257	0.322	0.302	0.017	0.058	0.229	0.288	0.240	0.027	0.109
02-Aug	0.276	0.317	0.308	0.014	0.045	0.210	0.269	0.228	0.020	0.008
03-Aug	0.279	0.319	0.303	0.014	0.047	•0.141	0.269	0.228	0.025	0.112
04-Aug	0.212	0.387	0.312	0.030	0.096	0.093	0.283	0.206	0.041	0.198
05-Aug	0.312	0.321	0.319	0.003	0.009	0.190	0.217	0.204	0.009	0.042
06-Aug	0.276	0.315	0.306	0.016	0.051	0.198	0.264	0.226	0.021	0.092
07-Aug	0.279	0.325	0.308	0.012	0.030	0.210	0.255	0.216	0.015	0.072
08-Aug	0.277	0.331	0.305	0.014	0.047	0.213	0.269	0.225	0.022	0.099
09-Aug	0.279	0.318	0.304	0.017	0.055	0.217	0.269	0.233	0.024	0.102
10-Rug	0.312	0.318	0.318	0.002	0.007	0.210	0.238	0.217	0.003	0.015
11-Aug	0.306	0.321	0.316	0.003	0.009	0.206	0.229	0.226	0.006	0.026
12-Aug	0.268	0.306	0.298	0.013	0.045	0.191	0.229	0.207	0.010	0.048
13-Aug	0.263	0.313	0.280	0.020	0.070	0.191	0.229	0.202	0.016	0.081
14-Aug	0.313	0.310	0.315	0,002	0.008	0.206	0.217	0.217	0.001	0.004
15-Aug	0.315	0.317	0.318	0.000	0.001	0.206	0.206	0.206	0.000	0.000
16-Rug	0.314	0.319	0.317	0.002	0.007	0.206	0.293	0.223	0.015	0.068
17-Aug	0.318	0.327	0.324	0.004	0.013	0.206	0.225	0.224	0.004	0.019
18-Aug	0.326	0.334	0.329	0.002	0.007	0.210	0.217	0.210	0.001	0.003
19-Rug	0.333	0.343	0.330	0.003	0.008	0.217	0.230	0.221	0.000	0.037
20-Aug	0.333	0.339	0.336	0.002	0.007	0.233	0.260	0.241	0.011	0.046
21-Rug	0.329	0.339	0.336	0.003	0.009	0.225	0.246	0.242	0.009	0.036
22-Aug	0.338	0,373	0.341	0.000	0.024	0.213	0.258	0.237	0.005	0.019
23-Aug	0.323	0.376	0.349	0.015	0.044	0.191	0.233	0.213	0.005	0.022

NA - Not Available

Table V.9

Rajangana: Daily coefficients of variation of main canal Water level at the control distributary canal, and daily coefficients of variation of discharge into the control distributary canal

	Water level (m)					Discharge (m3/s)				
Date (88)	Min.	Max.	Mean	STD	CV	Hin.	Max.	Mean	STO	CV
06-Jul	1.147	1.244	1.166	0.025	0.021	0.373	0.463	0.395	0.020	0.052
07-Jul	1.147	1.165	1.158	0.005	0.004	0.356	0.381	0.370	0.004	0.010
08-Jul	1.159	1.191	1.167	0.007	0.006	0.360	0.485	0.405	0.048	0.119
09-Jul	1.110	1.159	1.136	0.019	0.017	0.409	0.458	0.440	0,016	0.037
10-Jul	1.111	1.261	1.139	0.059	0.052	0.408	0.550	0.434	0.046	0.107
11-Jul	1.103	1.171	1.114	0.010	0.009	0.340	0.470	0.387	0.025	0.064
12-Jul	1.126	1.131	1.127	0.002	0.002	0.302	0.340	0.324	0.012	0.038
13-Jul	1.131	1.167	1.140	0.013	0.012	0.265	0.304	0.283	0.016	0.056
14-Jul	1.110	1.165	1.134	0.020	0.018	0.225	0.453	0.383	0.075	0.195
15-Jul	1.085	1.125	1.104	0.016	0.015	0.390	0.437	0.412	0.011	0.027
16-Jul	1.068	1.106	1.093	0.012	0.011	0.394	0.416	0.404	0.010	0.025
17-Jul	1.080	1.106	1.097	0.010	0.009	0.396	0.412	0.406	0.005	0.012
18-Jul	1.091	1.155	1.113	0.017	0.016	0.412	0.451	0.420	0.012	0.029
19-Jul	1.134	1.156	1.148	0.007	0.006	0.437	0.407	0.450	0.011	0.025
20-Jul	1.127	1.161	1.144	0.012	0.010	0.432	0.456	0.439	0.006	0.014
21-Jul	1.119	1.154	1.139	0.012	0.010	0.423	0.449	0.440	0.009	0.020
22-Jul	1.119	1.147	1.136	0.010	0.009	0.409	0.439	0.427	0.013	0.030
23-Jul	1.115	1.141	1.129	0.010	0.009	0.398	0.423	0.414	0.009	0.021
24-Ju1	1.123	1.150	1.135	0.010	0.009	0.394	0.425	0.411	0.008	0.020
25-Jul	1.106	1.139	1.122	0.012	0.011	0.409	0.437	0.418	0.009	0.022
26-Jul	1.101	1.132	1.119	0.011	0.010	0.432	0.495	0.447	0.018	0.041
27-Ju1	1.093	1.138	1.115	0.015	0.013	0.432	0.495	0.468	0.024	0.051
28-Jul	1.097	1.126	1.116	0.008	0.008	0.423	0.463	0.442	0.010	0.022
29-Jul	1.120	1.125	1.120	0.001	0.001	0.421	0.460	0.432	0.011	0.025
30-Jul	1.120	1.138	1.127	0.007	0.006	0.416	0.439	0.427	0.004	0.009
31-Jul	1.092	1.134	1.112	0.018	0.016	0.379	0.423	0.402	0.016	0.040
01-Aug	1.076	1.114	1.097	0.014	0.013	0.371	0.412	0.391	0.015	0.039
02-Aug	1.071	1.112	1.094	0.015	0.014	0.334	0.383	0.365	0.017	0.045
03-Aug	1.075	1.140	1.102	0.017	0.016	0.340	0.416	0.364	0.020	0.056
04-Aug	1.091	1.150	1.124	0.022	0.020	0.352	0,428	0.390	0.024	0.062
05-Aug	1.081	1.120	1.098	0.010	0.009	0.166	0.513	0.363	0.071	0.196
06-Aug	1.082	1.112	1.098	0.008	0.007	0.326	0.475	0.373	0.037	0.100
07-Aug	1.079	1.122	1.102	0.016	0.014	0.323	0.362	0.337	0.010	0.029
08-Aug	1.081	1.109	1.097	0.010	0.009	0.302	0.352	0.334	0.014	0.041
09-Aug	1.079	1.110	1.098	0.010	0.009	0.326	0.381	0.355	0.011	0.030
10-Aug	1,078	1.107	1.099	0.009	0.008	0.382	0.497	0.403	0.056	0.138
11-Aug	1.054	1.116	1.098	0.014	0.013	0,350	0.392	0.368	0.012	0.033
12-Aug	NA	NA	NA	NA	NA	0.154	0.350	0.286	0.068	0.239
13-Aug	NA	NA	NA	NA	NA	0.143	0.332	0.190	0.065	0.342
14-Aug	1.056	1.072	1.067	0.003	0.003	0.323	0.336	0.332	0.004	0.011
15-Aug	1.049	1.087	1.058	0.004	0.004	0.313	0.338	0.331	0.005	0.015
16-Aug	1.060	1.083	1.068	0.008	0.008	0.308	0.338	0.325	0.009	0.028
17-Aug	1.077	1.098	1.085	0.004	0.004	0.306	0.425	0.342	0.038	0.106
18-Aug	1.070	1.102	1.091	0.010	0.010	0.300	0.338	0.318	0.010	0.033
19-Aug	1.043	1.090	1.075	0.015	0.014	0.302	0.396	0,330	0.037	0.112
20-Aug	1.025	1.064	1.046	0.015	0.014	0.356	0.409	0.385	0.017	0.045
21-Aug	1.028	1.058	1.043	0.012	0.012	0.344	0.380	0.372	0.015	0.042
22-Aug	1.048	1.098	1.060	0.014	0.013	0.373	0.444	0.398	0.018	0.045
23-Aug	NA	NA	NA	NA	NA	0.242	0.453	0.378	0.077	0.203

NA - Not Available

Table V.10

SDA: Daily coefficients of Variation of rain canal water level (above bed of Parshall flume) and discharge at the headgate

	Water level (m)					Discharge (m3/s)				
Date (88)	Min.	Max.	Mean	STD	CV	Min.	Max.	Mean	STD	CV
11-Sep	1.512	1.594	1.533	0.026	0.017	8.449	9.392	8.766	0.314	0.036
12-Sep	1.571	1.734	1.623	0.062	0.038	8.854	10.621	9.545	0.497	0.052
13-Sep	1.486	1.737	1.635	0.0115	0.052	8.544	10.395	9.697	0.575	0.059
14-Sep	1.322	1.912	1.532	0.1110	0.123	6.706	12.126	8.798	1.635	0.186
15-Sep	1.136	1.893	1.392	0.253	0.182	5.444	11.796	7.534	1.935	0.257
16-Sep	0.933	1.308	1.112	0.111	0.099	3.414	7.334	5.213	1.152	0.221
17-Sep	0.884	1.248	1.017	0.126	0.124	2.763	5.083	3.759	0.617	0.164
18-Sep	1.017	1.585	1.241	0.188	0.151	2.985	8.353	5.057	1.709	0.338
19-Sep	1.068	1.538	1.291	0.176	0.136	4.728	7.865	6.117	1.081	0.177
20-Sep	1.068	1.681	1.387	0.1113	0.132	4.728	9.752	7.227	1.439	0.139
21-Sep	0.923	1.408	1.157	0.124	0.107	3.323	7.542	5.371	1.044	0.194
22-Sep	0.742	1.114	0.946	0.106	0.112	1.830	5.209	3.572	0.953	0.267
23-Sep	0.707	0.898	0.767	0.054	0.071	1.578	3.099	2.030	0.430	0.212
24-Sep	0.707	0.880	0.801	0.038	0.048	1.420	2.602	1.779	0.269	0.151
25-Sep	0.899	1.321	1.180	0.104	0.088	2.750	6.243	5.120	0.986	0.193
26-Seo	*0.686*	1.207	0.898	0.194	0.216	NA	NA	NA	NA	NA
27-Sep	0.719	0.752	0.732	0.010	0.014	1.663	1.904	1.760	0.073	0.041
28-Sep	0.129	*0.786*	0.749	0.021	*0.028*	1.735	2.164	1.885	0.160	*0.085*
29-Sep	0.783	1.200	0.951	0.170	0.178	2.140	5.443	3.428	1.329	0.388
30-Sep	0.738	0.893	0.768	0.026	0.034	1.800	2.657	2.000	0.145	0.072
01-Oct	0.738	1.136	0.968	0.109	0.174	NA	NA	NA	NA	NA
02-Oct	1.112	1.146	1.134	0.010	0.008	NA	NA	HA	NA	NA
03-Oct	0.752	1.112	0.952	0.152	0.159	NA	NA	NA	NA	NA
04-Oct	0.811	1.112	0.941	0.104	0.111	2.055	4.591	3.111	0.855	0.275
05-Oct	1.067	1.923	1.305	0.291	0.223	4.473	12.791	6.811	2.968	0.436
06-Oct	1.450	1.941	1.690	0.1111	0.107	9.092	12.857	10.792	1.216	0.113
07-Oct	1.053	1.450	1.241	0.135	0.109	4.575	9.092	6.670	1.547	0.232

NA - Not Availabls

Table V.11

SDA: Daily coefficients of variation of main canal water level (above invert of offtake) near Lateral B, and daily coefficients of variation of discharge into Lateral B

Date (88)	Water level (m) Min.	Max.	Mean	STD	CV	Discharge: Lateral B (m3/s) Min.	Max.	Mean	STD	CV
21-Jul	0.398	1.580	0.987	0.480	0.486	2.342	3.806	2.663	0.306	0.115
22-Jul	1.166	1.580	1.248	0.095	0.076	1.142	3.806	1.563	0.613	0.392
23-JUI	1.160	1.246	1.204	0.022	0.019	1.085	1.570	1.305	0.120	0.092
24-JUI	1.098	1.283	1.149	0.030	0.026	0.796	1.714	1.050	0.135	0.128
25-Jul	1.174	1.837	1.506	0.207	0.137	1.168	6.806	3.651	1.746	0.478
26-Jul	1.101	1.885	1.428	0.278	0.195	0.850	7.314	3.149	2.296	0.729
27-JUI	1.468	1.920	1.664	0.163	0.098	3.177	7.701	5.010	1.599	0.319
28-Jul	1.439	1.695	1.547	0.071	0.046	2.932	5.070	3.852	0.591	0.153
29-JU1	1.367	1.513	1.460	0.036	0.025	2.479	3.519	3.097	0.270	0.087
30-JUI	1.227	1.689	1.529	0.118	0.077	1.355	4.995	3.476	1.017	0.292
31-Jul	NA	NA	NA	NA	NA	0.358	1.691	1.296	0.376	0.290
01-Aug	NA	NA	NA	NA	NA	0.775	4.028	1.955	0.705	0.360
02-Aug	NA	NA	NA	NA	NA	1.073	4.099	1.843	0.770	0.418
03-Aug	NA	NA	NA	NA	NA	0.348	1.073	0.622	0.249	0.401
04-Aug	NA	NA	NA	NA	NA	0.337	3.506	0.509	0.534	1.049
05-Aug	NA	NA	NA	NA	NA	0.337	6.362	2.915	1.261	0.432
06-Aug	1.174	1.813	1.526	0.232	0.152	1.079	5.931	3.419	1.614	0.472
07-Aug	1.242	1.885	1.632	0.240	0.147	1.468	6.743	4.267	1.925	0.451
08-Aug	1.090	1.679	1.417	0.203	0.143	0.807	4.640	2.675	1.314	0.491
09-Aug	1.269	1.667	1.475	0.115	0.078	1.637	4.435	2.958	0.814	0.275
10-Aug	1.143	1.499	1.330	0.114	0.086	0.924	2.813	1.875	0.648	0.345
11-Aug	0.248	1.176	0.956	0.226	0.237	0.362	1.042	0.620	0.255	0.411
12-Aug	0.621	1.169	1.009	0.183	0.182	0.362	1.061	0.709	0.228	0.322
13-Rug	0.471	1.427	0.972	0.205	0.210	0.366	2.479	0.620	0.391	0.630
14-Aug	0.326	1.137	0.634	0.324	0.511	0.348	0.901	0.497	0.216	0.434
15-Aug	NA	NA	NA	NA	NA	0.072	0.775	0.365	0.300	0.823
16-Aug	NA	NA	NA	NA	NA	0.072	2.488	1.306	0.675	0.517
17-Aug	1.340	1.573	1.511	0.058	0.038	1.880	3.265	2.747	0.334	0.122
18-Aug	1.502	1.831	1.602	0.081	0.051	2.632	5.206	3.352	0.619	0.185
19-Aug	1.490	1.531	1.508	0.016	0.010	2.525	2.994	2.722	0.114	0.042
20-Aug	1.525	1.561	1.543	0.013	0.008	2.624	3.190	2.868	0.109	0.038
21-Aug	1.506	1.564	1.540	0.017	0.011	2.563	3.197	2.911	0.125	0.043
22-Aug	1.440	1.512	1.500	0.008	0.005	2.563	2.830	2.703	0.057	0.021
23-Aug	1.479	1.548	1.499	0.013	0.009	2.614	3.121	2.783	0.100	0.036
24-Aug	1.501	1.783	1.600	0.057	0.036	2.873	5.091	3.488	0.428	0.123
25-Aug	1.465	1.667	1.563	0.052	0.034	2.746	4.205	3.388	0.375	0.111
26-Aug	1.209	1.459	1.366	0.049	0.036	1.240	2.793	2.114	0.297	0.140
27-Aug	0.905	1.196	1.044	0.068	0.065	0.299	1.187	0.600	0.197	0.329
28-Aug	0.772	1.045	0.968	0.061	0.063	0.072	0.545	0.317	0.176	0.555
29-Aug	NA	NA	NA	NA	NA	0.072	1.012	0.403	0.355	0.883
30-Aug	NA	NA	NA	NA	NA	0.796	1.777	1.276	0.297	0.232
31-Aug	NA	NA	NA	NA	NA	1.446	1.875	1.626	0.127	0.078
01-Sep	1.139	1.391	1.293	0.075	0.058	0.807	2.093	1.486	0.376	0.253
02-Sep	NA	NA	NA	NA	NA	0.340	0.918	0.607	0.196	0.323
03-Sep	NA	NA	NA	NA	NA	0.072	0.600	0.205	0.173	0.843
04-Sep	NA	NA	NA	NA	NA	0.388	1.504	0.675	0.214	0.317
05-Sep	NA	NA	NA	NA	NA	0.407	2.360	1.237	0.732	0.592
06-SOP	NA	NA	NA	NA	NA	1.958	2.353	2.168	0.104	0.048
07-Sep	NA	NA	NA	NA	NA	0.595	4.767	2.464	1.039	0.421
08-Sep	NA	NA	NA	NA	NA	1.174	3.240	1.899	0.461	0.243
09-Sep	NA	NA	NA	NA	NA	0.586	2.054	1.030	0.556	0.540
10-Sep	NA	NA	NA	NA	NA	0.366	1.246	0.974	0.253	0.260
11-Sep	NA	NA	NA	NA	NA	0.480	0.619	0.532	0.031	0.058
12-Sep	NA	NA	NA	NA	NA	0.591	5.988	3.330	2.089	0.627
13-Sep	NA	NA	NA	NA	NA	4.013	5.613	4.919	0.429	0.087
14-SOP	NA	NA	NA	NA	NA	0.072	4.262	1.556	1.556	1.000
15-Sep	NA	NA	NA	NA	NA	0.464	1.745	0.743	0.234	0.315
16-Sep	NA	NA	NA	NA	NA	0.072	0.976	0.492	0.266	0.540
17-Sep	NA	NA	NA	NA	NA	0.072	0.337	0.076	0.031	0.411
18-Sep	NA	NA	NA	NA	NA	0.072	0.834	0.231	0.204	0.882
19-Sep	NA	NA	NA	NA	NA	0.514	4.653	2.196	1.125	0.512
20-Sep	NA	NA	NA	NA	NA	2.271	5.840	4.068	1.028	0.253
21-Sep	NA	NA	NA	NA	NA	0.072	3.219	1.340	1.153	0.860
22-Sep	NA	NA	NA	NA	NA	0.072	0.801	0.159	0.168	1.054
23-Sep	NA	NA	NA	NA	NA	0.072	0.351	0.087	0.063	0.725
24-Sep	NA	NA	NA	NA	NA	0.072	0.072	0.072	0.000	0.000
25-Sep	NA	NA	NA	NA	NA	0.072	0.072	0.072	0.000	0.000
26-SOP	NA	NA	NA	NA	NA	0.072	1.446	0.505	0.399	0.792
27-Sep	NA	NA	NA	NA	NA	0.484	1.665	0.834	0.257	0.308
28-Sep	NA	NA	NA	NA	NA	0.072	0.924	0.396	0.348	0.879
29-Sep	NA	NA	NA	NA	NA	0.072	1.098	0.372	0.396	1.067
30-Sep	NA	NA	NA	NA	NA	0.072	0.723	0.151	0.159	1.048
01-Oct	NA	NA	NA	NA	NA	0.072	0.072	0.072	0.000	0.000
02-Oct	0.368	0.447	0.414	0.023	0.056	0.072	0.072	0.072	0.000	0.000
03-Oct	NA	NA	NA	NA	NA	0.072	1.753	0.643	0.510	0.793
04-Oct	NA	NA	NA	NA	NA	1.048	2.744	1.711	0.592	0.346
05-Oct	NA	NA	NA	NA	NA	0.577	3.336	2.004	1.002	0.500
06-Oct	1.585	1.943	1.689	0.105	0.062	NA	NA	NA	NA	NA
07-Oct	1.037	1.615	1.289	0.203	0.157	0.476	2.877	1.463	0.802	0.548

NA - Not Available

Table .V.12

SDA: Daily coefficients of variation of main canal water level (above invert of offtake) near Lateral O, and daily coefficients of variation of discharge into Lateral O

Date (88)	Water level (m) Min.	Max.	Mean	STD	CV	Discharge (m3/s) Min.	Max.	Mean	STD	CV
21-Jul	0.364	1.381	*0.560*	0.18'	0.334	0.001	0.155	0.004	0.016	3.903
22-Jul	0.307	0.406	0.400	0.05:	0.128	0.001	0.015	0.004	0.005	1.143
23-Jul	0.077	1.162	0.308	0.31	0.811	0.000	0.002	0.001	0.001	1.033
24-Jul	0.098	1.081	0.455	0.34:	0.752	0.000	0.031	*0.008*	0.012	1.435
25-Jul	0.794	1.081	0.962	0.10"	0.109	0.002	0.000	0.030	0.025	0.049
26-Jul	0.764	1.508	1.061	0.2411	0.234	0.002	0.495	*0.065*	0.146	2.244
27-Jul	0.693	1.393	0.918	0.200	0.224	0.002	0.177	0.006	0.018	3.136
20-Jul	0.499	0.853	0.745	0.05	0.076	0.002	0.432	0.114	0.179	1.564
29-Jul	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30-Jul	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
31-Jul	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
01-Aug	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
02-Aug	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
03-Aug	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
04-Aug	0.064	1.430	0.784	0.39	0.499	*0.000*	0.004	0.263	0.258	0.983
05-Aug	0.084	0.660	0.205	0.15	0.760	0.000	0.224	0.023	0.062	2.734
06-Aug	0.562	1.205	0.672	0.17	0.282	0.150	0.535	0.219	0.100	0.456
07-Aug	0.729	0.816	0.174	0.024	0.031	0.245	0.297	0.264	0.013	0.040
08-Aug	0.781	1.104	0.905	0.10	0.110	0.192	0.270	0.230	0.029	0.121
09-Aug	0.861	0.914	0.898	0.00	0.009	0.186	0.193	0.191	0.003	0.017
10-Aug	0.737	0.609	*0.650*	0.04	*0.055*	0.180	0.272	0.221	0.038	0.160
11-Aug	0.456	0.741	0.621	0.07	0.117	0.094	0.269	0.170	0.031	0.219
12-Aug	0.539	1.346	0.908	0.296,	0.328	0.130	*0.560*	0.340	0.152	0.447
13-Aug	0.521	1.375	0.940	0.291	0.309	0.125	0.443	0.303	0.121	0.398
14-Aug	0.236	1.133	0.533	0.376	0.709	0.000	0.392	0.122	0.173	1.420
15-Aug	0.143	0.230	0.214	0.02:	0.136	0.000	0.000	0.000	0.000	1.871
16-Aug	0.086	1.127	0.165	0.39	0.520	0.000	0.720	0.361	0.253	0.700
17-Aug	0.939	0.987	0.965	0.01	0.016	0.626	0.663	0.657	0.019	0.030
16-Aug	0.983	1.243	1.130	0.10	0.091	0.659	0.922	0.616	0.096	0.118
19-Rug	1.072	1.205	1.199	0.06	0.054	0.216	0.799	0.397	0.250	0.630
20-Aug	1.060	1.131	1.084	0.014	0.013	0.206	0.250	0.218	0.014	0.003
21-Aug	0.670	1,507	0.830	0.106	0.224	0.250	0.666	0.331	*0.066*	0.201
22-Aug	0.723	1.336	1.101	0.27	0.247	0.078	0.342	0.196	0.091	0.467
23-Aug	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
24-Aug	0.935	1.105	1.019	0.03	0.035	0.621	0.184	0.714	*0.032*	0.045
25-Rug	0.030	1.100	0.999	0.07	0.079	0.550	0.019	0.744	0.091	0.122
26-Aug	0.923	1.110	0.991	0.05	0.051	0.296	0.742	0.400	0.193	0.401
27-Aug	0.541	0.970	0.818	0.16	0.207	0.114	0.296	0.233	0.070	0.300
28-Aug	0.073	0.541	0.443	0.131	0.295	0.000	0.114	*0.036*	0.041	1.284
29-Aug	0.076	1.257	0.847	0.476	0.562	0.000	0.035	0.090	0.168	1.875
30-Rug	*0.506*	1.217	1.000	0.241	0.247	0.005	0.519	0.095	0.144	1.508
31-Aug	0.673	1.142	0.989	0.131	0.138	*0.006*	0.531	0.268	0.158	0.593
01-Sep	0.729	1.089	0.957	0.128	0.134	0.007	0.415	0.140	0.151	1.081
02-Sep	0.916	1.083	1.003	0.061	0.061	*0.006*	0.007	*0.006*	0.001	0.008
03-Sep	0.082	1.102	0.871	0.351	0.403	0.000	0.000	0.005	0.002	0.453
04-Sep	0.201	1.120	0.715	0.319	0.412	0.000	0.009	0.005	0.003	0.535
05-Sep	0.616	1.240	0.043	0.198	0.236	0.005	0.204	0.108	0.125	1.150
06-Sep	1.058	1.240	1.103	0.038	0.034	0.000	0.007	0.005	0.001	0.129
07-Sep	0.068	1.148	0.003	0.371	0.462	0.000	0.005	0.004	0.002	0.472
08-Sep	0.194	1.345	0.828	0.440	0.531	0.000	0.452	0.037	0.061	1.660
09-Sep	0.872	1.452	1.206	0.076	0.063	0.021	1.004	0.421	0.233	0.554
10-Sep	1.087	1.350	1.181	0.090	0.016	0.123	1.008	0.681	0.249	0.365
11-Sep	0.989	1.323	1.111	0.115	0.104	0.113	1.076	0.049	0.126	0.149
12-Sep	0.406	1.043	0.695	0.160	0.178	0.123	0.759	0.507	0.190	0.325
13-Sep	0.337	0.979	0.538	0.145	0.270	0.005	0.586	0.113	0.166	1.469
14-Sep	0.509	1.390	0.867	0.279	0.322	0.003	0.131	0.016	0.028	1.569
15-Sep	1.130	1.444	1.298	0.076	0.059	0.016	0.300	0.460	0.275	0.597
16-Sep	0.795	1.239	0.953	0.162	0.110	0.301	0.774	0.403	0.118	0.245
17-Sep	0.604	1,369	0.048	0.233	0.276	*0.008*	0.499	0.208	0.117	0.400
10-Sep	0.440	1.193	0.677	0.19'2	0.203	0.073	0.411	0,198	0.088	0.446
19-Sep	0.212	0.403	0.376	0.091	0.257	0.000	0.088	0.040	0.034	0.704
20-Sep	NA	NA	NA	NA	NA	0.000	0.192	0.028	0.060	2.173
21-Sep	0.276	0.639	0.474	0.124	0.261	0.004	0.167	0.090	0.067	0.604
22-Sep	0.355	0.580	0.465	*0.063*	0.135	0.029	0.156	0.091	0.038	0.415
23-Sep	0.395	1.160	0.921	0.271	0.294	0.051	0.042	0.430	0.231	0.527
24-Sep	0.476	1.070	0.775	0.193	0.249	0.103	0.525	0.300	0.140	0.455
25-Sep	0.699	1.301	1.079	0.130	0.120	0.235	0.630	0.485	0.094	0.194
26-Sep	0.908	1.298	1.140	0.131	0.120	0.217	0.501	0.314	0.086	0.275
27-Sep	0.305	1.298	0.945	0.307	0.325	0.009	0.468	0.236	0.009	0.376
28-Sep	0.058	1.120	0.683	0.375	0.549	0.000	0.725	0.330	0.309	0.913
29-Sep	0.058	0.443	0.242	0.118	0.487	0.000	0.004	0.002	0.002	1.024
30-Sep	0.404	1.284	0.637	0.261	0.410	0.002	1.002	0.111	0.238	2.155
01-Oct	0.069	0.621	0.497	0.135	0.279	0.000	0.002	0.002	0.000	0.233
02-Oct	0.069	0.265	0.177	0.064	0.301	0.000	0.000	0.000	0.000	3.047
03-Oct	0.090	1.270	0.453	0.268	0.588	0.000	0.090	*0.006*	0.016	2,749
04-Oct	0.263	1.164	0.066	0.350	0.403	0.003	0.005	0.004	0.001	0.276
05-Oct	0.184	1.372	0.749	0.391	0.523	0.000	0.125	0.007	0.010	2.580
06-Oct	0.795	0,869	0.851	0.028	0.033	0.003	0.003	0.003	0.000	0.004
07-Oct	*0.606*	0.922	0.740	0.098	0.132	0.003	0.483	0.216	0.162	0.751

NA - Not Available

Table V. 13

Rotational values of delivery height (volume/area/days) of Kalankuttiya Branch Canal, yala 1988.

Period	No. days	Date		MS1, Area 800.94 ha					Near DBM1, 305D3: Area 54.23 ha					Tail-end, 307D3, Area 109.67 ha				
		From	To	Rain	Delivery - Rain	Delivery + Rain	+ Rain mm/day	- Rain mm/day	Rain	Delivery - Rain	Delivery + Rain	+ Rain mm/day	- Rain mm/day	Rain	Delivery - Rain	Delivery + Rain	+ Rain mm/day	- Rain mm/day
LP	15	08-nay	22-nay	41	268	309	21	18	41	180	221	15	12	20	253	275	18	17
R1	8	23-May	30-May	0	109	109	14	14	0	87	87	11	11	0	90	90	11	11
R2	8	31-May	07-Jun	3	13	76	10	3	3	72	IS	9	Y	46	39	65 -	1T	
R3	13	08-Jun	20-Jun	14	148	161	12	11	14	153	166	13	12	11	112	123	9	9
R4	7	21-Jun	27-Jun	1	104	105	15	15	1	94	95	14	13	I	89	90	13	13
R5	7	28-Jun	04-Jul	0	104	104	15	IS	0	80	60	11	11	2	82	84	12	11
R6	10	05-Jul	14-Jul	57	60	117	12	6	57	44	101	10	4	74	28	102	10	3
R7	10	15-Jul	24-Jul	I	116	123	12	12	I	106	113	11	11	3	71	74	7	1
R8	a	25-Jul	01-Aug	0	121	121	15	15	0	89	89	11	11	6	116	122	15	14
R9	8	02-Aug	09-Aug	0	116	116	15	15	0	111	111	14	14	0	111	111	14	14
R10	3	10-Aug	18-Aug	123	63	186	21	7	123	98	221	25	11	74	31	104	12	3
R11	18	19-Aug	05-Sep	23	186	208	12	10	23	120	143	a	7	30	203	232	13	11
R12	15	06-Sep	20-Sep	170	122	292	19	a	170	65	235	16	4	86	151	236	16	10
R13	5	21-Sep	25-Sep	30	56	66	11	11	30	54	84	17	11	9	35	43	9	7
Total far C1 to R12:				461	1641	2114			467	1354	1821			359	1411	1712		

Table *V.14*

Rotational values of cumulative delivery height (volume/area) of Kalankuttiya Branch Canal, yala 1988

Period	No. days	Date From	Date To	MS1, Area 800.94 ha Rain	MS1, Area 800.94 ha Delivery - Rain	MS1, Area 800.94 ha Delivery 4 Rain	Near DBW1, 30503: Area 54.23 ha Rain	Near DBW1, 30503: Area 54.23 ha Delivery - Rain	Near DBW1, 30503: Area 54.23 ha Delivery 4 Rain,	Tail-end, 30703, Area 109.67 ha Rain	Tail-end, 30703, Area 109.67 ha Delivery - Rain	Tail-end, 30703, Area 109.67 ha Delivery t Rain
LP	15	08-May	22-May	41	268	309	41	180	221	20	253	215
R1	8	23-Hay	30-Hay	41	377	418	41	267	308	20	343	365
R2	8	31-Hay	07-Jun	44	151	495	44	339	383	66	383	451
R3	13	08-Jun	20-Jun	57	599	656	57	492	549	17	495	574
R4	7	21-Jun	27-Jun	58	703	161	58	587	645	78	5s4	664
R5	7	28-Jun	04-Jul	58	308	866	58	666	725	19	666	747
R6	10	05-Jul	14-Jul	115	367	983	115	711	826	153	694	849
R7	10	15-Jul	24-Jul	122	983	1105	122	817	939	156	166	924
R8	8	25-Jul	01-Aug	122	1104	1226	122	906	1028	162	882	1046
R9	8	02-Aug	09-Aug	122	1220	1342	122	1016	1138	162	992	1156
R10	9	10-Aug	18-Aug	215	1284	1528	245	1115	1359	235	1023	1260
R11	18	19-Aug	05-Sep	267	1469	1736	267	1235	1502	265	1226	1493
R12	15	06-Sep	20-Sep	437	1591	2028	431	1300	1731	350	1376	1729
R13	5	21-Sep	25-Sep	467	1547	2114	467	1354	1821	359	1411	1772
Total for C1 to R12:				467	1547	2114	467	1354	1821	359	1411	1772

Table V.15 Pattern of daily water volume distribution along the Kalankuttiya branch canal for two selected water issue periods R1 & R4 *, Yala 1988

Date	Volume of water distributed to distributary canals (m3)																		Total issue to DCs (m3)	Volume measured at MS1 (m3)	Conveyance loss %
	305D2	305D3	308D2	305D4	306D1	308D3	306D2	309D1	306D3	309D2	306D4	309D3	306D5	309D4	309D5	307D1	307D2	307D3			
Period R1 (23 - 26 May)																					
23-May	4122	6826	5643	4118	5150	8158	6349	4996	2131	2116	3583	6335	9852	6449	6155	2921	5162	11318	101181	151825	-
24-May	10705	14083	10032	6816	10031	13503	11500	8564	5244	3866	1165	10566	20122	13658	13130	6386	7180	20045	192401	219609	-
25-May	10705	14602	10032	6116	10031	13503	11500	8564	5211	4003	7165	10084	16311	13458	10295	6386	7585	29111	195408	235514	-
26-May	4684	1364	1285	2840	8364	5626	9586	5109	4310	8688	1461	9815	13836	11215	8027	8545	12686	38215	111358	182102	-
Sub total	30911	42854	29992	20590	34187	40189	38934	21833	17589	18670	25380	36800	60121	44579	31601	24245	33212	98155	662955	195650	16.7
Period R4 (21 - 24 June)																					
21-Jun	1186	3110	6419	3025	5227	9015	5810	7341	3118	3280	4030	6981	9662	6245	6314	3415	5216	9850	106085	169856	-
22-Jun	10950	8461	10032	4686	10560	8391	11500	9788	6865	5626	1165	12920	20122	12234	14115	7097	9336	28944	198804	233313	-
23-Jun	10950	11491	6851	6684	10560	8391	11500	9188	6865	3293	1165	14030	20154	12234	631	6214	12482	30612	181962	231232	-
24-Jun	4220	11405	2112	1854	3160	3411	1901	2855	3146	996	3135	8053	8889	2441	6341	1352	8511	27734	111113	133101	-
Sub total	33306	34474	26015	14246	30088	29221	36777	29111	20594	13196	21495	11984	58821	33161	21461	21138	35551	97200	604565	161162	21.2
Total	64122	11328	56067	34836	64215	70010	75711	57604	38183	31866	66815	18184	118948	77740	65068	45382	68163	195355	1261519	1563212	18.9

* The periods were selected in such a way to avoid interuption by rain fall and extensions in uater issues.

Table V.16 **Water deliveries dong the Kalankuttiya Branch Canal for two selected water issue periods R1 & K4 *, Yala 1988**

Channel No./ Structure	Distance from the head sluice (m)	Distance from the D/S 08 weir (m)	Area cultivated (ha)	Water issue period: R1 Duration (day)	Issue (m3)	Issue (mm)	Issue (mm)/day	Water issue period: R4 Duration (day)	Issue (m3)	Issue (mm)	Issue (mm)/day
Head sluice	0	3250									
Cross regulator	138										
MS1	178		8(1	3.58	195650	99	28	3.10	161562	96	28
1305 02	2056	1194	40	2.99	30811	77	26	3.08	33306	83	27
305 03	3119	71	54	2.99	42854	79	26	3.04	34114	63	21
308 02	3239	11	34	-		-				-	-
DB weir - 1	3250										
305 D4	3635	723	35	3.02	20590	58	19	3.04	14246	40	13
306 D1	1193	165	43	3.11	34181	79	23	2.88	30088	69	24
308 D3	4331	21	56	-		-				-	-
DB weir - 2	4358										
306 02	4585	7	47			-				-	-
DB ueir - 3	4592										
309 D1	5341	168	31			-				-	-
DB ueir - 4	5509										
306 03	6085	89	21	3.35	11589	72	22	3.00	20594	85	28
309 02	6150	24	17							-	-
DB ueir . 5	6174										
Drop structure-1	6114										
306 D4	6500	7	25	3.33	25380	103	31	3.00	21495	87	29
1309 03	6500	7	39	3.34	36800	94	28	3.21	1984.1	108	33
DB weir - 6	6501										
Drop structure-?	7116										
306 D5	8340	2	83	3.32	60121	68	21	3.00	58821	67	22
D8 ueir . 1	a312										
309 D4	8134	3 1	43	-						-	-
DB weir - 8	8131										
1309 05	9860	3 1	4?	3.30	31601	90	21	3.02	21161	65	22
DB ueir - 9	9863										
307 D1	10563		31	3.35	24245	82	24	3.20	21138	71	22
307 D2	10920		38	3.40	33212	87	26	3.22	35551	94	29
307 03	10920		113	3.10	98755	90	21	3.30	91200	89	27

* Yater issue period R1: 23May - 26May; Yater issue period Rd: 21 June - 24 June
- Computations were not performed in respect of canals where assesment of flow was considered inadequate

Assumotions made by the agency:

Field water requirement	:	64 mm per week (i.e 2.5 inches per week or water 1
Oistributary canal requirenent (asruaing 10 % losses in DC 8 Fcs)	:	10 mm per week (per water issue)
Head sluice requirenent (assuming 15 % BC loss)	:	80 mm per week (per water issue)
Irrigation interval	:	7 days
Duration of water issue	:	3 days
Therefore, distributary canal requirement/day	:	23 mm
head sluice requirement/day	:	27 mm

Table V.17 Kalankuttiya: Estimation of water lost due to leak through the head sluice gate during non water issue periods as measured at staff gauge MS1 (Area = 801 ha)

Issue period	Duration (days)			Leak		Water delivery during total period (mm)	Leak as % of total issue
	Total	Issue	Non-issue	(m3)	(mm)		
LP	15	13	2	44,044	5	268	2
R1	8	4	4	74,287	9	109	9
R2	8	3	5	86,324	11	73	15
R3	13	7	6	140,572	18	148	12
R4	7	4	3	59,214	7	104	7
R5	7	4	3	53,513	7	104	6
R6	10	3	7	189,266	24	60	39
R7	10	5	5	121,512	15	116	13
R8	8	5	3	66,800	8	121	7
R9	8	5	3	60,853	8	116	7
R10	9	2	7	181,558	23	63	36
R11	18	6	12	358,512	45	186	24
R12	15	4	11	303,408	38	122	31
R13	5	5	0	0	0	56	0
Whole season	141	70	71	1.74E+06	217	1646	13

Note:

1. The capacity of the Kalankuttiya tank is 1.86 x 10^6 m3. Therefore, the total amount lost due to leak through the damaged head sluice qate (1.14 x 10^6 m3) is approximately 94 % of the total tank capacity.

2. The leak accounts for 13 % of the total water delivered over the season and it is sufficient to give at least one additional rotational water issue to Kalankuttiya block.

Table V.18
Daily average water delivery per unit cultivated area during esch period of inflow along SOA Wain Canal, 21 July to 07 October 1988.

Period of inflou	No. of days	Start date	End date	Head 8055 (mm/day)	U/S Lateral 8 1031 (mm/day)	literal B 2852 (mm/day)	D/S lateral B 4178 (mm/day)	U/S Lateral G 1866 (mm/day)	Lateral G 722 (mm/day)	D/S lateral G 1144 ha. (mm/day)
P1	4	21-Jul	24-Jul	NA	3.4	5.0	2.4	NA	NA	NA
P2	6	25-Jul	30-Jul	NA	10.3	11.2	9.7	NA	NA	NA
P3	5	31-Jul	04-Aug	NA	3.4	3.8	3.1	NA	NA	NA
P4	7	05-Aug	11-Aug	NA	1.1	8.1	1.4	NA	2.3	NA
P5	5	12-Aug	16-Aug	NA	1.6	2.1	1.3	NA	2.1	NA
P6	11	17-Aug	27-Aug	NA	8.0	8.2	7.8	NA	5.2	NA
P7	11	28-Aug	07-Sep	NA	3.2	3.4	3.0	2.0	0.8	2.8
P8	4	08-Sep	11-Sep	NA	8.3	3.4	11.1	1.7	6.0	8.8
P9	3	12-Sep	14-Sep	10.0	1.4	9.9	5.8	6.5	2.9	8.8
P10	5	15-Sep	19-Sep	5.9	5.1	2.3	1.0	8.6	3.5	11.9
P11	2	20-Sep	21-Sep	6.8	4.2	8.2	1.5	2.9	0.8	4.2
P12	4	22-Sep	25-Sep	3.4	1.6	0.3	2.4	3.2	4.0	2.6
P13	3	26-Sep	28-Sep	2.4	1.2	1.8	0.8	2.2	3.5	1.3
P14	4	29-Sep	02-Oct	1.5	1.5	0.5	2.1	2.5	0.3	3.9
P15	5	03-Oct	07-Oct	5.9	5.0	5.8	4.1	4.1	0.6	1.3
Total volume (m3)				10,401,586	28,582,836	11,675,184	16,907,652	3,255,185	1,284,791	2,596,178
No. of days				26	79	79	79	41	64	41
Daily mean (mm/day)				5.0	5.1	5.2	5.1	4.3	2.8	5.5
(before 12 September)										
Total volume (m3)				NA	21,805,129	8,973,838	12,831,291	989,510	863,282	752,012
No. of days				NA	53	53	53	15	38	15
Daily mean				NA	5.9	5.9	5.8	3.5	3.1	4.4
[from 12 September to 07 October)										
Total volume (m3)				10,401,586	6,171,108	2,701,346	4,076,361	2,265,614	421,509	1,844,165
No. of days				26	26	26	26	26	26	26
Daily mean				5.0	3.1	3.6	3.8	4.1	2.2	6.2

Table V.19 Kirindi Oya Right Eank Main Canal: Comaprison of actual water delivery with theoretical targets during some crop growth stages

Distributory Canal: DC5 (Command area : 181.2 ha)

Starting Date	End Date	Number Days	Crop Stage	Target (m3)	Target (m3/d)	Target (mm/d)	Actual (m3)	Actual (m3/d)	Actual (mm/d)	Difference (Actual-Target) as % of target
20-Mar	21-Mar	2	Stage 4 a	39,398	19,699	10.9	29550	14775	8.2	-25 a
22-Mar	07-Apr	17	Stage 5 b	95,766	5,633	3.1	211162	12421	6.9	120
08-Apr	09-May	-	-	-	-	-	-	-	-	-
10-May	14-Jun	36	Stage 1	1,183,032	32,862	18.1	1083434	30095	16.6	-8
15-Jun	28-Jun	14	Stage 2 c	316,276	22,591	12.5	457191	32657	18.0	45
Whole observation period:		69		1,634,472	23,688	13.1	1,781,337	25,816	14.2	9

a Stage 3 data was not available. Monitoring period covered only 2 days in stage 4

b *Duration of stage 5 was extended beyond the initially planned 7 days*

c a part of Stage 2

\- no water issues for 32 days between two cultivation seasons

Branch canal: BC2 (Command area : 528 ha)

Starting Date	End Date	Number Days	Crop Stage	Target (m3)	Target (m3/d)	Target (mm/d)	Actual (m3)	Actual (m3/d)	Actual (mm/d)	Difference (Actual-Target) as % of target
20-Mar	20-Mar	1	Stage 2 a	80,248	80,248	15.2	56066	56066	10.6	-30 a
21-Mar	15-May	56	Stage 3	5,617,382	100,310	19.0	4226445	15472	14.3	-25
16-May	22-May	7	Stage 4	491,521	70,211	13.3	593201	84743	16.0	21
23-May	14-Jun	23	Stage 5 b	461,428	20,062	3.8	768496	33413	6.3	61
Whole observation period:		87		6,6110,580	16,443	14.5	5,644,209	64,876	12.3	-15

a Stage I data was not available. Monitoring period covered only I day In Stage 2

b Duration of stage 5 was extended beyond the initially planned 1 days

ANNEX 1111

A rotation during the week beginning 12 September 1988

A ROTATION DURING THE WEEK BEGINNING 12 SEPTEMBER 1988

By mid-September, because of the failure of the rains in August (93 mm against 400 mm expected according to past records), the Pantabangan Reservoir elevation was at the lowest since 1983. As a result, in the Santo Domingo Area (SDA), the Zone Engineer and the Water Management Technicians (WMTs) worked out a new irrigation delivery plan for the area, with effect from Monday, 12 September 1988. It was based on a weekly rotation among Laterals along the SDA Main Canal. During the previous week (before 10 September), the Water Central Coordinating' Center, Cabanatuan (WCCC) had allocated about 15 m³/sec to District I. At the beginning of the current week, the target flow had been reduced to 10 m³/sec, following information communicated to the WCCC by the Hydrologist of District I, that the area had received some rain. Of the 10 m³/sec, 4 m³/sec was supposed to be diverted at the SDA Supply Headgate to complement the local flow estimated at around 2 m³/sec. Thus, the intended inflow into SDA Main Canal at 5-Bay intake was about 6 m³/sec since Monday 12 September for the 9.568 hectares (ha) irrigated from that source. The Zone Engineer considered this supply short compared to supply in normal situations averaging 9 m³/sec.

As the new rotation plan came into effect, Lateral B received the total amount of the available water at its Checkgate, from 0800 h on Monday up to 0800 h on Wednesday, IIMI's record at that level indicated that this operation was effectively achieved on time by closing fully the sole gate of the Main Checkgate that can be operated, despite extensive damage to this structure. Except for about 4 hours at the beginning of the rotation for which Lateral B was given about 3.5 m³/sec, it had been flowing at nearly maximum capacity for the duration of the rotation. By 8.00 h on Wednesday, the same checkgate was lifted by the gatekeeper, allowing the water 'surface in the upstream reach of the main canal to drop below the offtake level of Lateral B cutting short the diversion, so that the SDA Main Canal downstream and Lateral E and E-X could take over on their turn in the rotation schedule.

During the first day, the Water Management Technicians allocated water to the upper portion of Lateral B while the lower portion was given water the second day. However, the Technician in charge of the lower portion of Lateral B said that 24 hours was too short for him to complete irrigation of his section and that he would need an additional 8 hours or *so*, for which he wanted to request permission from his Zone Engineer.

On the following afternoon, there was heavy rainfall in the command area, lasting for more than two hours. The Water Management Technicians, while pleased with this rain, were wondering how the "management" would respond. Would SDA receive more water or would WCCC cut off the supply in response to the rain? They hoped that there would be no further reduction of the supply.

We learnt the following day that information regarding the rain had been communicated without delay to the WCCC, which took quick action to establish a new flow target. The hydrologist of District 1 not only informed the WCCC of the rainfall by radio, but placed a standing request for 5 m³/sec at RG#3 so that DC1 would keep a minimum flow to prevent emptying it, which would otherwise require 1 or 2 days to refill.

On Thursday morning, we learnt while interviewing the Operation Engineer for the District, that the Head of the WCCC actually dropped in at the District Office the previous afternoon and informed the Operation Engineer of the new supply target of 5 m^3/sec. Thus the hydrologist who was with us during this interview, received the information at the same time as we did. He further said that this discharge was supposed to be shared equally between zone 2 and zone 3 on the assumption that the local flow available at 5-Bay would be larger. Based on his experience, he assumed that for such a rain intensity, 3.5 m^3/sec of runoff would be available to complement 2.5 m^3/sec to be diverted at the Supply Headgate.

Thus, the intended inflow into SDA Main at 5-Bay intake was supposed to be about 6 m^3/sec on Thursday, 15 September after the rain, i.e., actually no reduction in the supply target for the SDA, compared to the supply target before the rain. On Thursday afternoon, we visited DC1. At the SDA Supply Headgate, the water level in DC1 was high but the flow diverted was surprisingly less than expected. Flashboards placed across a lateral escape allowed the level in the parent canal to rise by about 30 centimeters (cm) above Full Supply Depth. In the diverting creek, a staff gauge indicated "17" which corresponds to a discharge of 1.74 m^3/sec only instead of 2.5 m^3/sec as planned. The estimate was made according to the calibration table maintained by the hydrologist which he keeps in his personal notebook! The hydrologist explained to us that it is possibly the result of an intervention by farmers of Zone 2, who may have closed that gate temporarily to draw more into their turnout. This indeed was plausible because the Headgate is neither locked nor watched as the gatekeeper in charge resides some distance away from the gate. We were also told that previous attempts to lock that gate with a padlock or other means were not successful as farmers tampered with it. During times of serious water crisis the NIA's staff even weld the gate, as well as other larger structures across DC1 to prevent farmers changing the gate settings. Presently, there is only one gate out of two working at the SDA Supply Headgate, the second one having been broken during maintenance work done by NIA along the canal. Moving along DC1, we found Radial Gate #3 open up to graduation "100". Only one gate of the three radial gates was functioning. The two other gates were out of order and kept in a closed position. This created additional difficulties when high flows had to be conveyed through DC1. Given the water depth in the upstream reach (about 1 meter below FSD) e.g., a head of 1.85 meters over a gate opening of 0.85 meters, we could estimate the flow passing through RG#3 using the UPRIIS/NIA Water Measurement Table - July 1977. This document was established specifically for the system structures at the time of commissioning the system. The hydrologist had a copy of this booklet at hand. Thus the estimated flow was 7 m^3/sec, i.e., more than the 5 m^3/sec as planned by WCCC.

On Friday morning, 16 September, we discussed with the hydrologist our observations made on the field, the day before. He actually had planned to inspect DC1 at this time, the first time since Wednesday's rain, and we decided to accompany him. When we arrived at SDA Supply Headgate we found that it was opened wider than before, although the level in DC1 had dropped

Next >>

Figure 3. GR12 - Gates' opening, 27 March 1988 1200 h to 29 March 1988 1200 h.

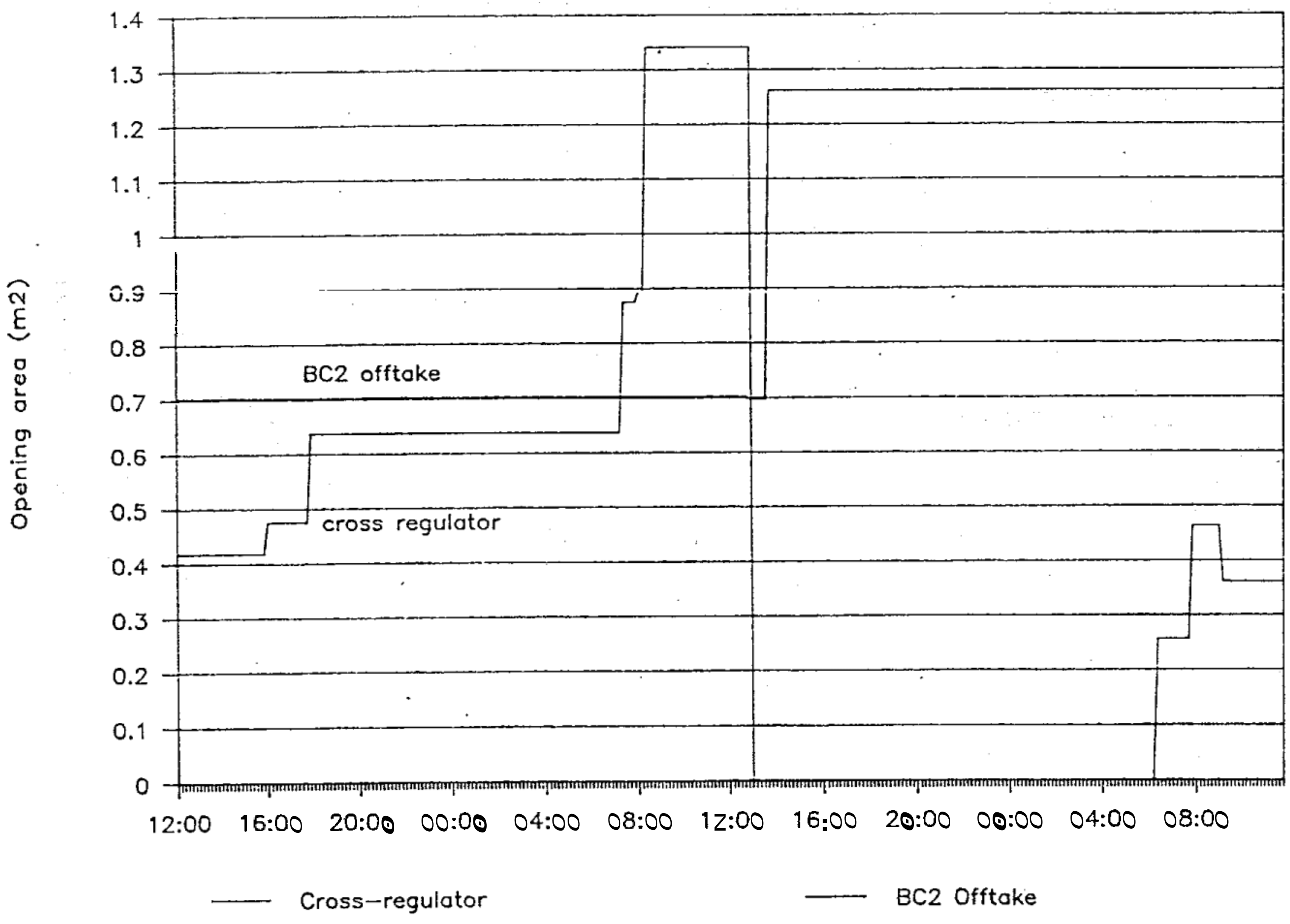


Figure 4. GR12 - Flows. 27 March 1988 1200 h to 29 March 1988 1200 h.

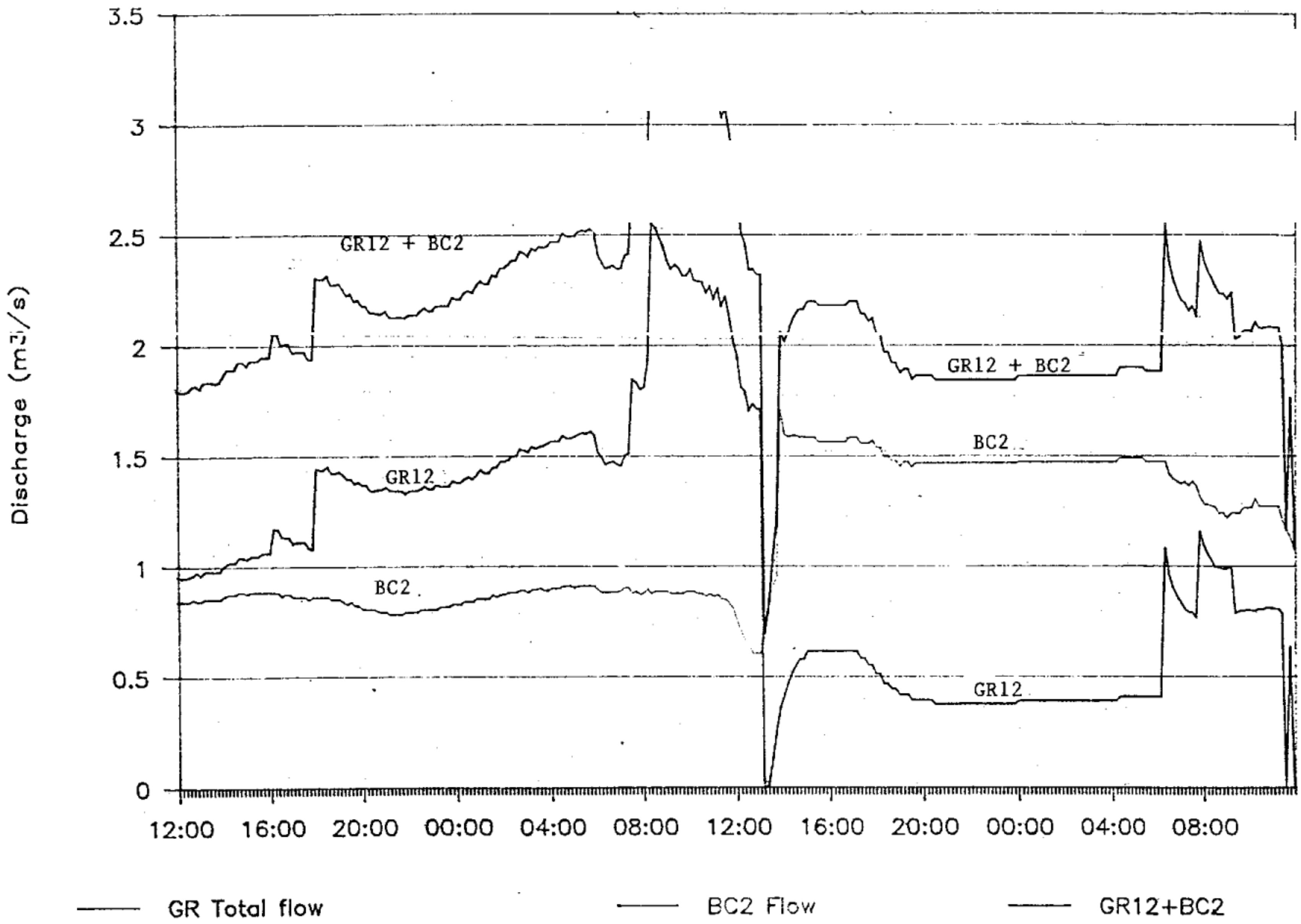


Figure 5. BC2 flow evaluation: submergence impact, 27 March 1988 1200 h to 29 March 1988 1200 h.

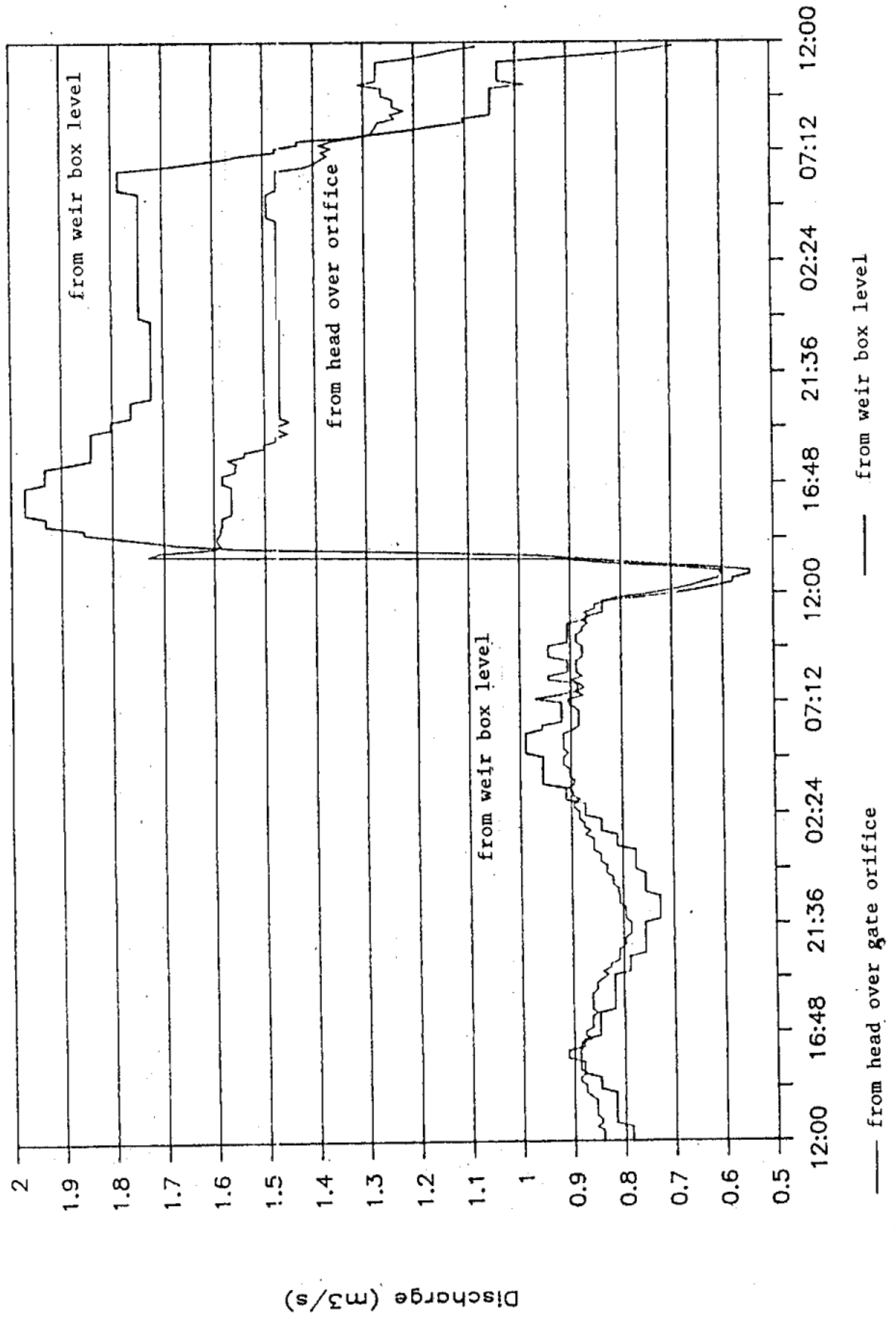
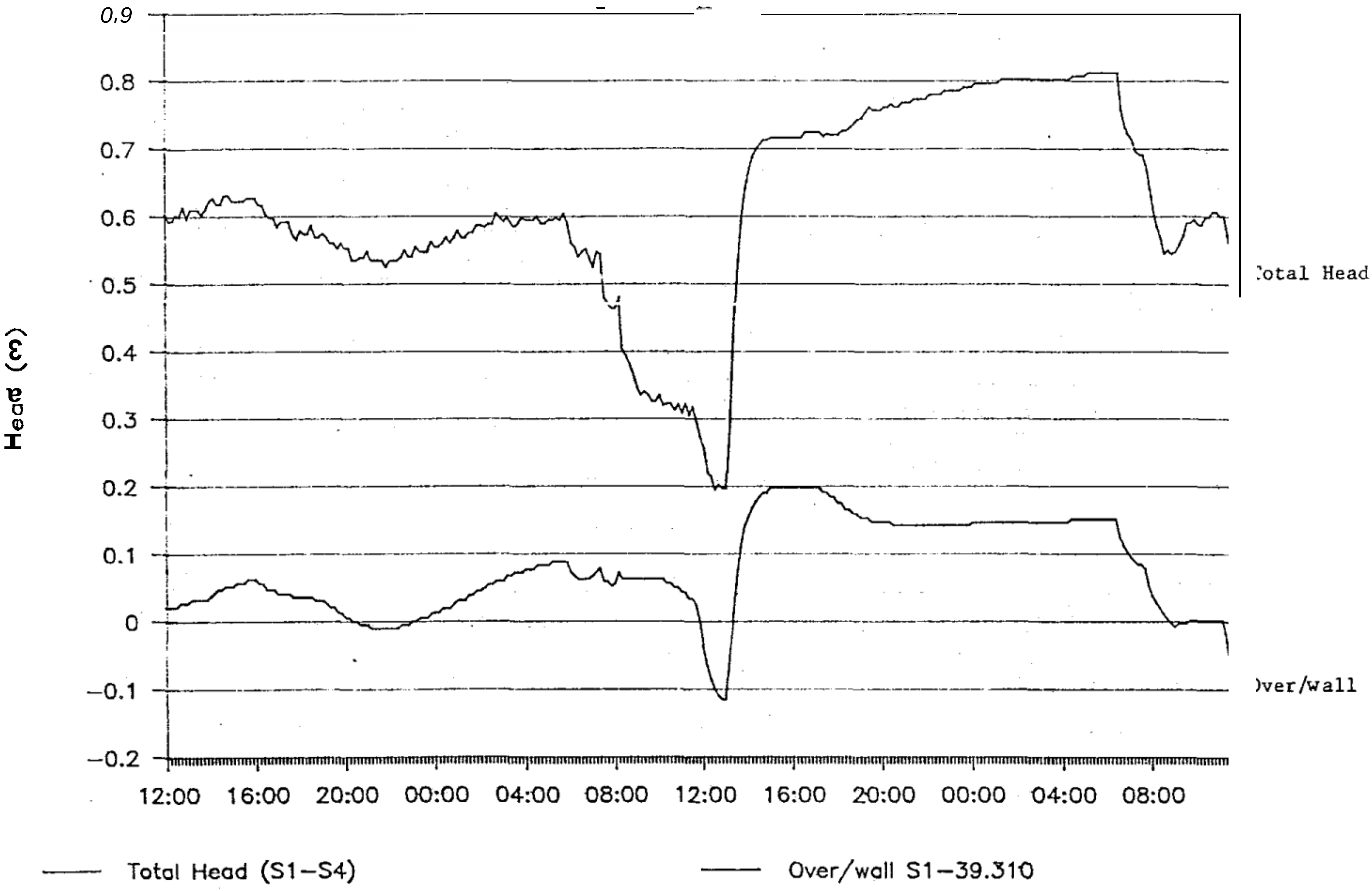


Figure 6. GR12 - Total head and head over sidewalls, 27 March 1988 1200 h to 29 March 1988 1200 h.



ANNEX V.1

Kalankuttiya: Sensitivity of discharge in distributary canal 307D3 to water level variations in branch canal

ANNEX V.1 Kalankuttiya: Sensitivity of discharge in 307D3 to water level variation in branch canal.

The tail-end distributary 307D3 has two openings which are 60 cm in diameter. The measuring device consists of a broad crested weir having a length of 3.3 meters and a crest elevation of 90.062 meters above mean sea level (MSL). The distributary canal (DC) functions as the drainage for the Kalankuttiya subsystem as well. Thus, its gates were fully opened and never manipulated throughout the season. There was no check structure located in the DC immediately downstream of the offtake gate to generate backwater effect that might have influenced the flow through the offtake. Therefore, the hydraulic head that controls discharge into the distributary canal will only depend on the water level in the branch canal.

The discharge in the distributary canal was estimated by making use of the water level record from the electronic datalogger installed downstream of the broad-crested weir and the previously established calibration equation between the water level in the DC at this point and measured discharge rates.

Since the tail-end reach of the branch canal (BC) is poorly regulated, the water level in the BC is highly unstable even within a single day of water issue. Therefore, a few days of water issue periods yield a data set that displays a wide range of variation in branch canal water level and in corresponding distributary canal discharge rate which could be used to derive a relationship between these two variables.

For this purpose, the water level in the branch canal and the corresponding discharge rate in the distributary canal recorded at 10 minute intervals between 14/05/1988 aid 25/05/1988 by the datalogger were used. 953 data points were extracted from approximately 1,500 data points by excluding data outside periods of water issue (approximately 3 days of flow outside water issue periods were present between these two dates). The distributary canal flow rates corresponding to a particular value of branch canal water level were averaged (weighted for the number of occurrences) and a data set of 27 pairs of water level and discharge was finally obtained.

A linear regression analysis was performed between the square root of the branch canal water level above the invert of the offtake (89.852 meters above MSL) and the discharge rate in the distributary canal. The following results were obtained:

Regression Output:

Constant	-737.458
Standard Error of Y Est	11.737
R Squared	0.992
Number of Observations	27
Degrees of Freedom	25
X Coefficient	162.744
Standard Error of Coefficient	2.975

The relationship between branch canal water level above the invert of the offtake and the discharge in 307D3 can thus be expressed as:

$$Q = -737.458 \ t \ 162.744 \ H^{0.5}$$

where,

Q = Distributary canal discharge (liters/sec), and
H = Branch canal water level above pipe invert level (cm).

A value of -737.458 was obtained for the intercept as the weir crest of the distributary canal was 21 cm above the pipe invert level (89.853 and 90.062 meters, respectively). Figure 1 shows the observed values and the line of best fit. Figure 2 is another interpretation of the above calibration curve which shows the sensitivity of discharge in the distributary canal (expressed in terms of the percentage change in discharge) to a change in the branch canal water level (i.e., the operating head). The incremental change in branch canal level up to 10 cm has been considered, in 2 cm steps. From figure 2 it is seen that the sensitivity of distributary canal discharge to a given change in branch canal water level decreases with the increase in operating head.

Table 1 summarizes the entire computations and results.

The average water level in the branch canal over the season has been 44 cm above the invert of the offtake while the daily **standard** deviation of water levels in the branch canal varies between 4 cm and 10 cm (25th and 75th percentiles, respectively), with a mean of 7 cm. This suggests that the water level in the branch canal could fluctuate between 37 and 51 cm within a day of water issue.

From figure 1, the mean branch canal water level of 44 cm above the invert level of the offtake of distributary canal 307D3 (which determines the hydraulic head at the offtake) corresponds to a discharge of 342 liters/sec in 307D3.

Figure 2 indicates that the discharge could vary by approximately t24 percent or -26 percent of the above discharge (342 liters/sec) if the branch canal level deviates by t7 cm or -7 cm about the mean value of 44 cm.

The percentage variation of discharge corresponding to a given deviation of branch canal water level from any other value of hydraulic head at the 307D3 offtake can be similarly determined from Figure 2.

Table 1. Computational Table related to the Sensitivity of discharge in 307D3 to water level variation in branch canal.

H * (cm)	Q measured (l/s)	Sqrt(H)	Q estimated (l/s)	dQ/Q (dH=2)	dQ/Q (dH=4)	dQ/Q (dH=6)	dQ/Q (dH=8)	dQ/Q (dH=10)	dQ/Q (dH=-2)	dQ/Q (dH=-4)	dQ/Q (dH=-6)	dQ/Q (dH=-8)	dQ/Q (dH=-10)
34	207	5.8	211	12	26	38	50	62	-13	-27	-42	-56	-72
35	217	5.9	225		24	35	46	57	-12	-25	-38	-52	-86
36	239	6.0	239	11	22	33	43	53	-12	-23	-36	-48	-61
31	257	6.1	252	10	21	31	40	50	-11	-22	-33	-45	-57
38	278	6.2	286		19	29	38	47	-10	-20	-31	-42	-53
39	289	6.2	279	9	18	27	36	44		-19	-29	-40	-50
41	325	6.4	305	6	16	24	32	39	-8	-17	-26	-35	-45
42	305	6.5	317	8	15	23	30	37	-8	-16	-25	-33	-42
44	-	6.6	342	7	14	21	27	34	-7	-15	-22	-30	-38
45	314	6.7	354	1	13	20	26	33	-7	-14	-21	-29	-36
46	354	6.8	366	6	13	19	25	31	-7	-13	-20	-27	-35
47	379	6.9	378	6	12	18	24	30	-6	-13	-19	-26	-33
48	398	6.9	390	6	12	18	23	29	-6	-12	-19	-25	-32
49	397	7.0	402	6	11	17	22	28	-6	-12	-18	-24	-31
50	414	7.1	413	6	11	16	21	27	-6	-11	-11	-23	-29
51	406	7.1	425	5	11	16	21	26	-5	-11	-17	-22	-20
52	417	7.2	436	5	10	15	20	25	-5		-16	-22	-27
53	420	7.3	441	5	10	15	19	24	-5	-10	-15	-21	-26
54	448	7.3	458	5	9	14	19	23	-5	-10	-15	-20	-25
56	401	7.5	480	4	9	13	18	22	-5	-9	-14	-19	-24
51	495	7.5	491	4	3	13	17	21	-4	-9	-14	-18	-23
50	501	7.6	502	4	8	12	16	20	-4	-9	-13	-18	-22
59	504	7.1	513	4	8	12	16	20	-4	-0	-13	-17	-22
60	534	1.1	523	4	8	12	16	19	-4	-8	-12	-17	-21
63	571	7.9	554	4	7	11	14	18	-4	-8	-11	-15	-19
68	612	8.2	605	3	6	10	13	16	-3	-7	-10	-13	-17
71	644	8.4	634	3	6	9	12	15	-3	-6	-9	-13	-16
14	656	8.6	663	3	6	8	11	14	-3	-6	-9	-12	-15

* measured above the pipe invert level of 307 D3

\- not available

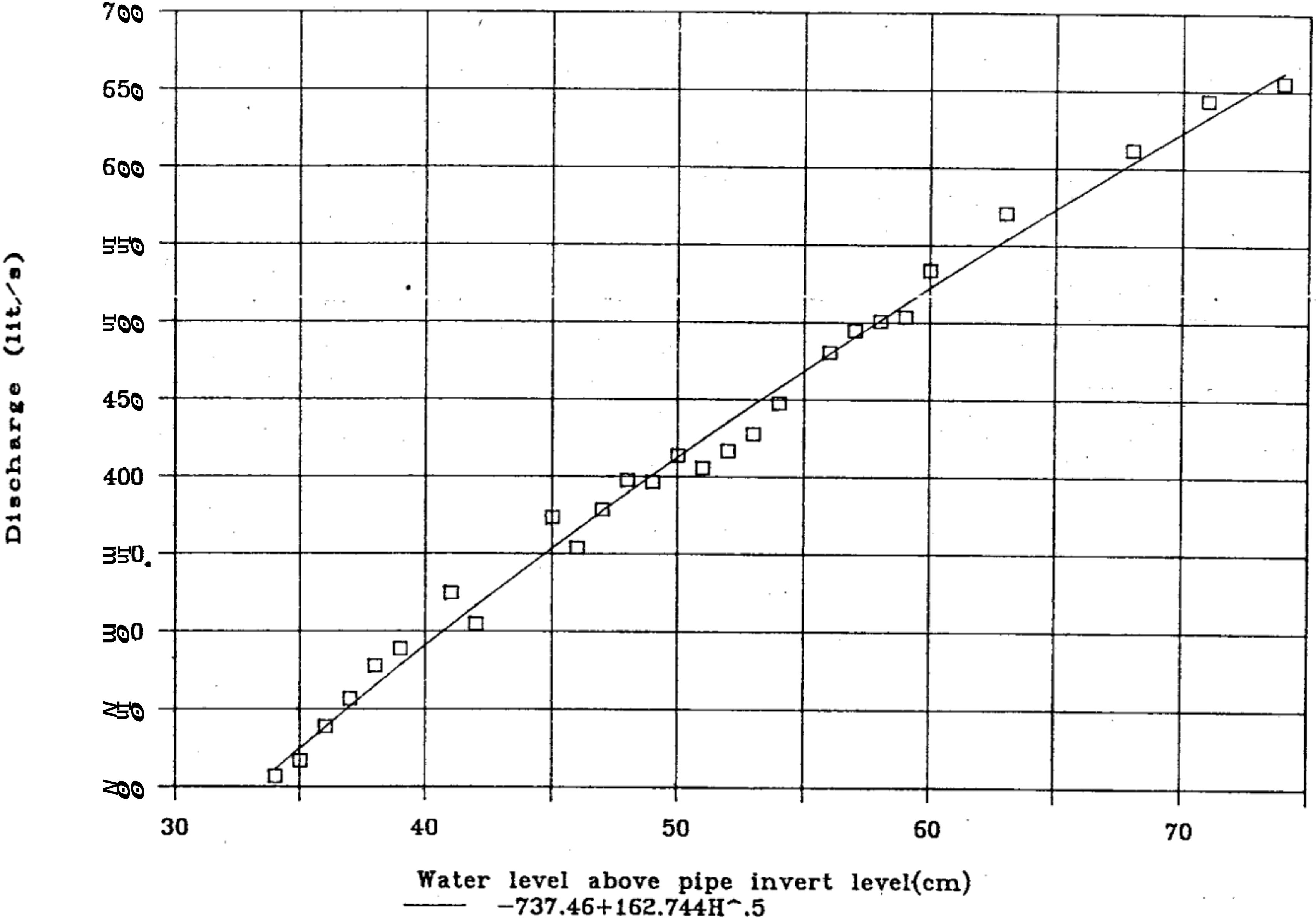
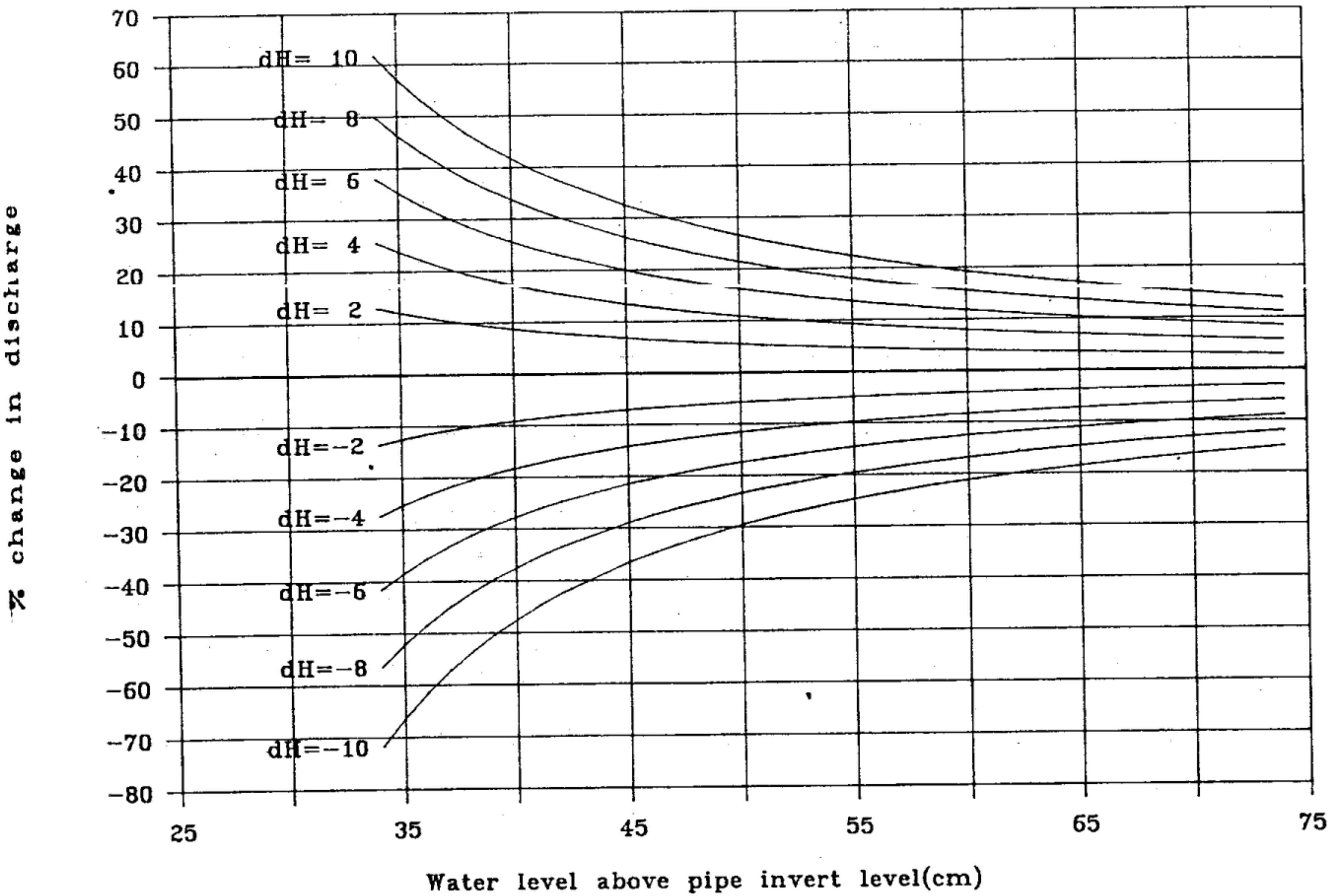


Figure 1 Kalankuttiya: Relationship between Maio C≡n≡l water level and discharge in distributary canal 307 D3

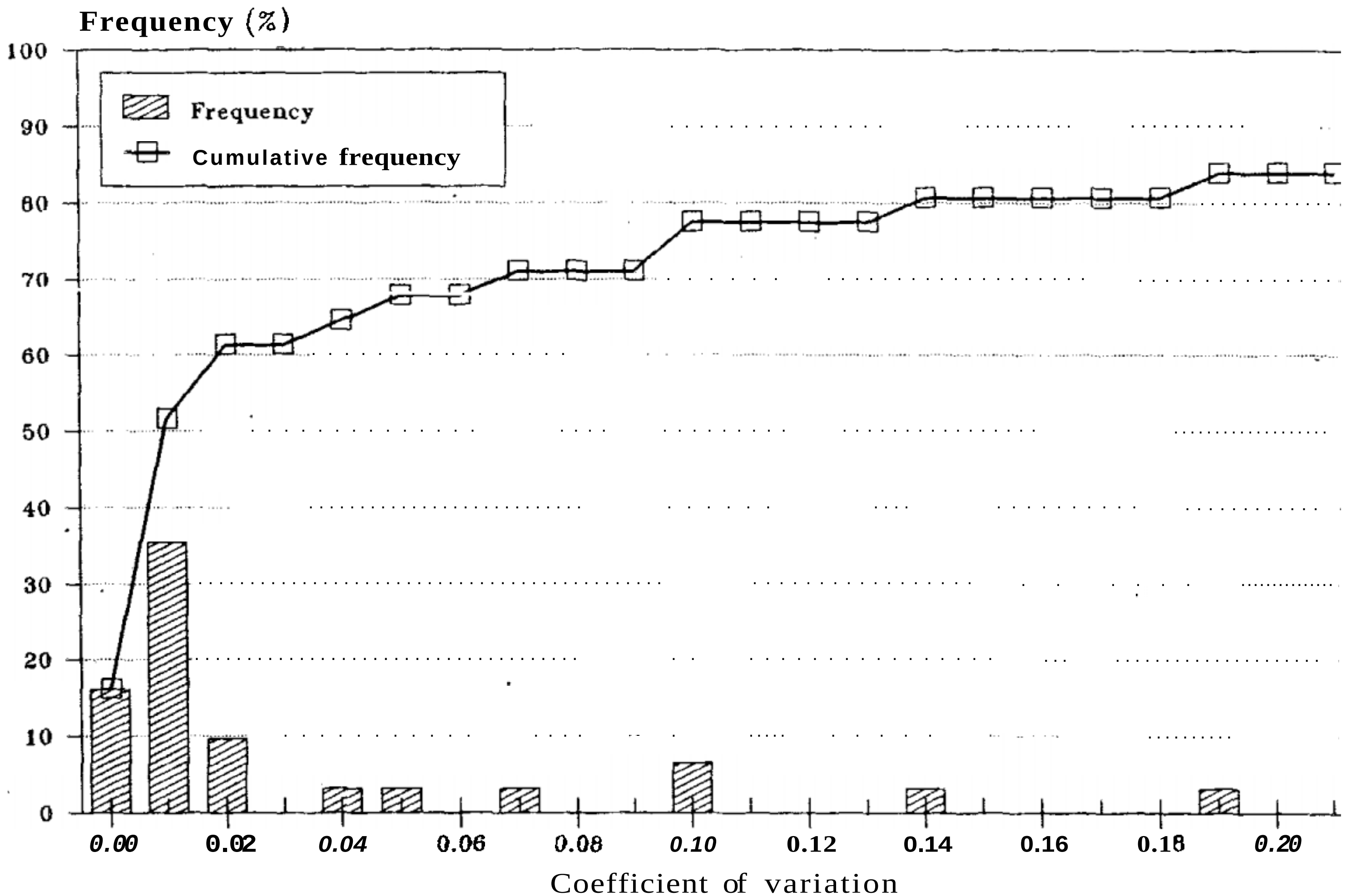
Figure 2. Kalankuttiya: Sensitivity of discharge in distributary canal 307D3 to water level variation in branch canal



ANNEX V.2

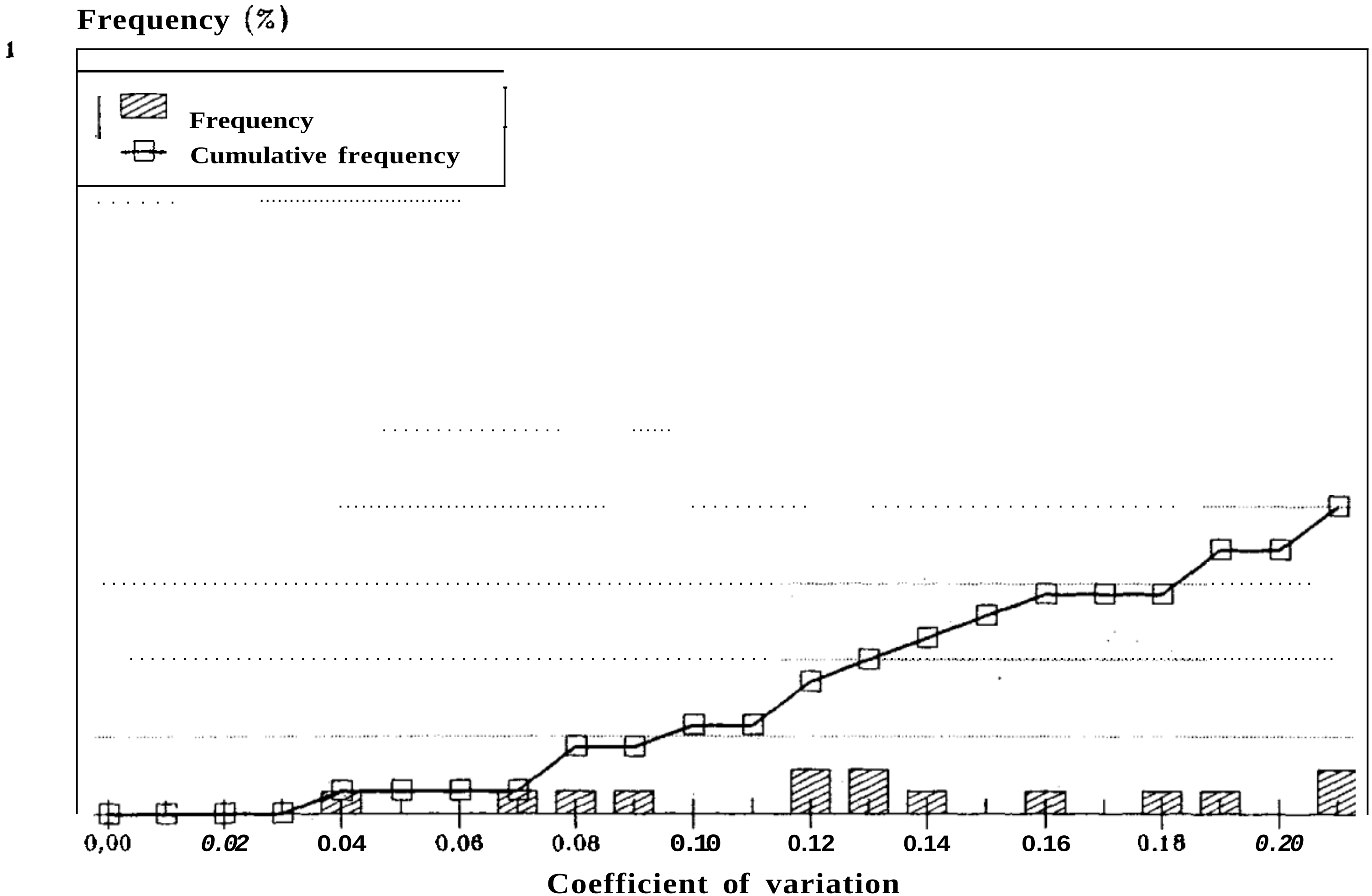
Frequency distributions of coefficient of variation of discharge in the distributary / main canals studied

Kalankuttiya: Distribution of coefficient of variation of discharge in 305 D 3



Average CV ≈ 0.083

Kalankuttiya: Distribution of coefficient of variation of discharge in 307 D3



Average CV ≈ 0.361

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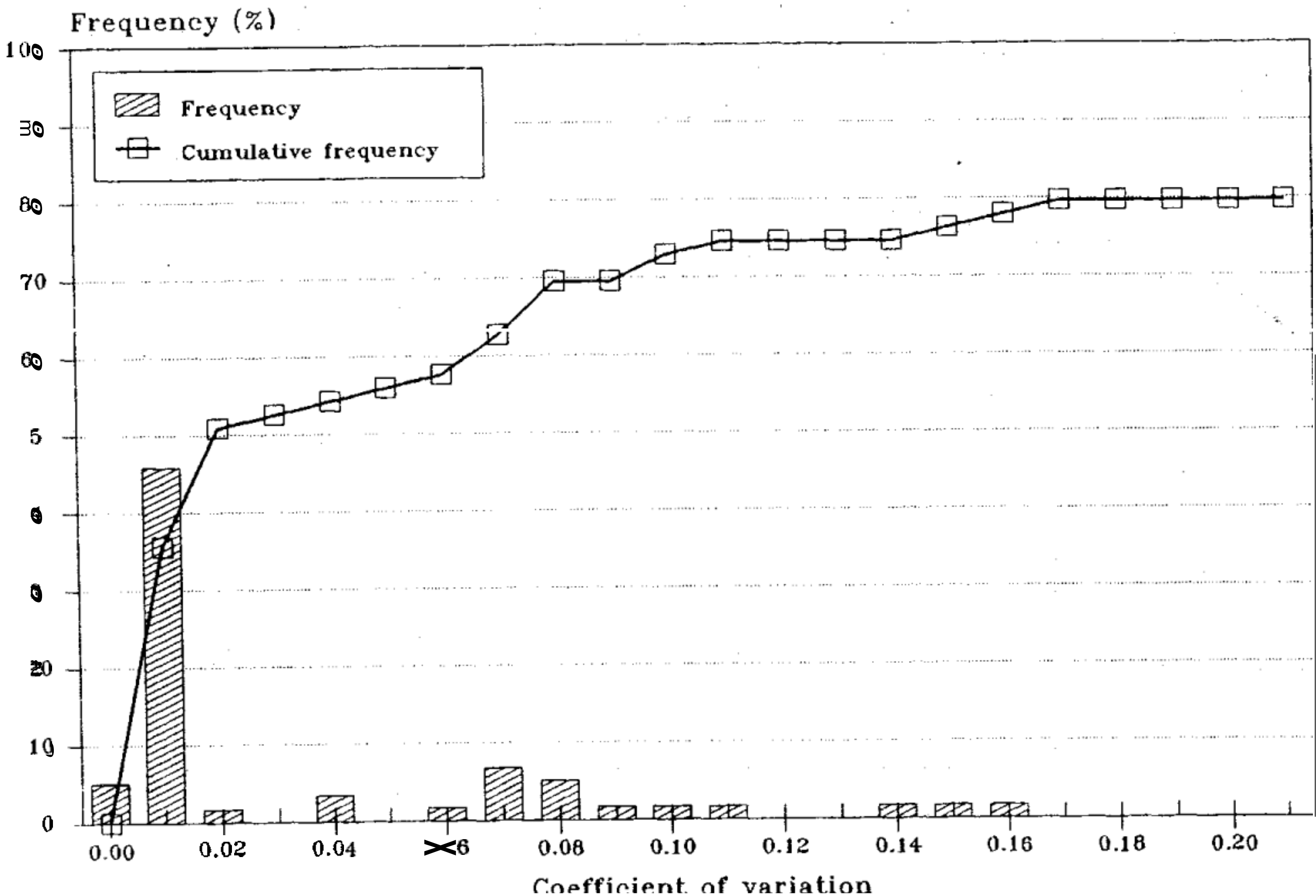
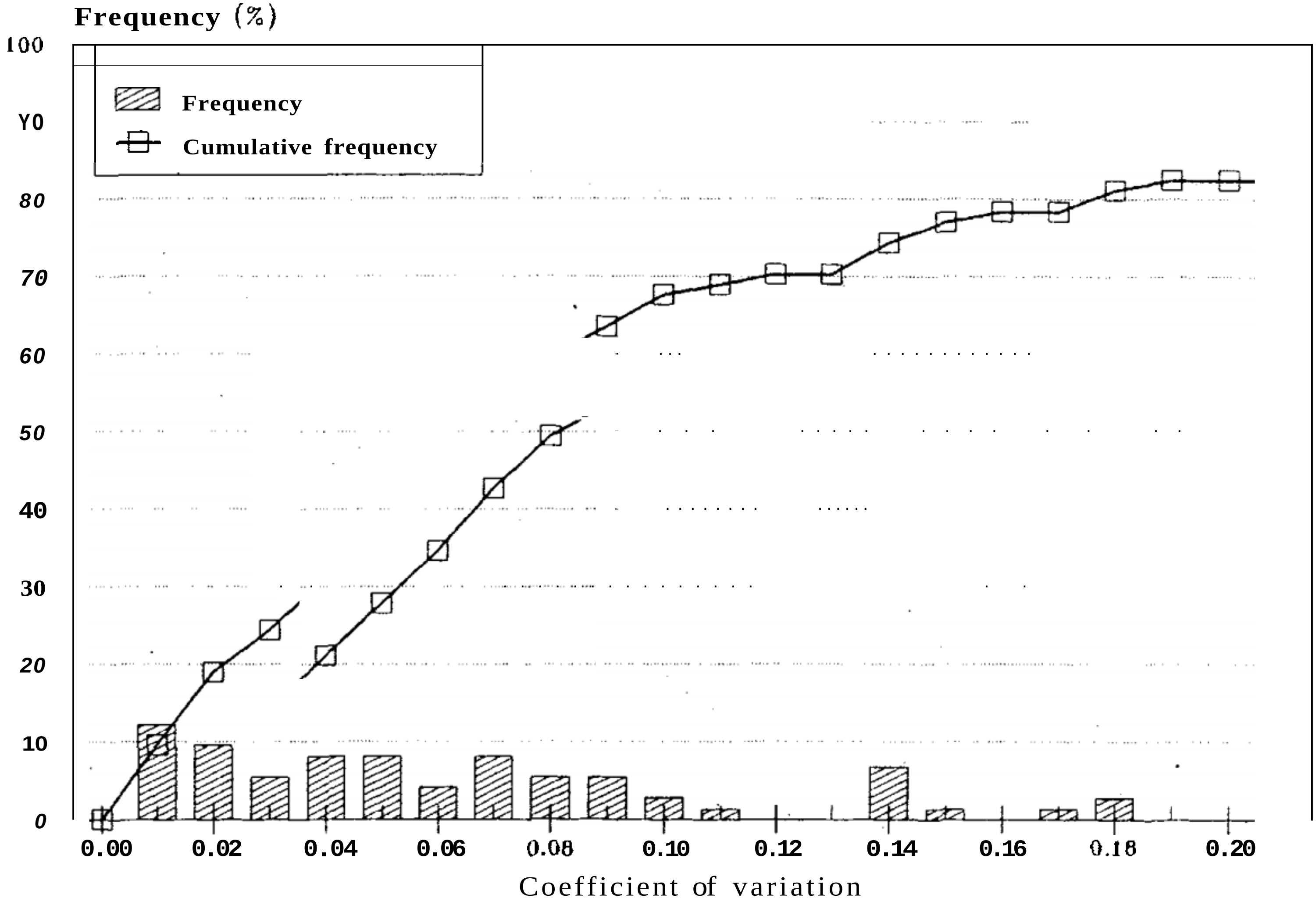
Kirindi Oya: Distribution of coefficient of variation of discharge in DC5



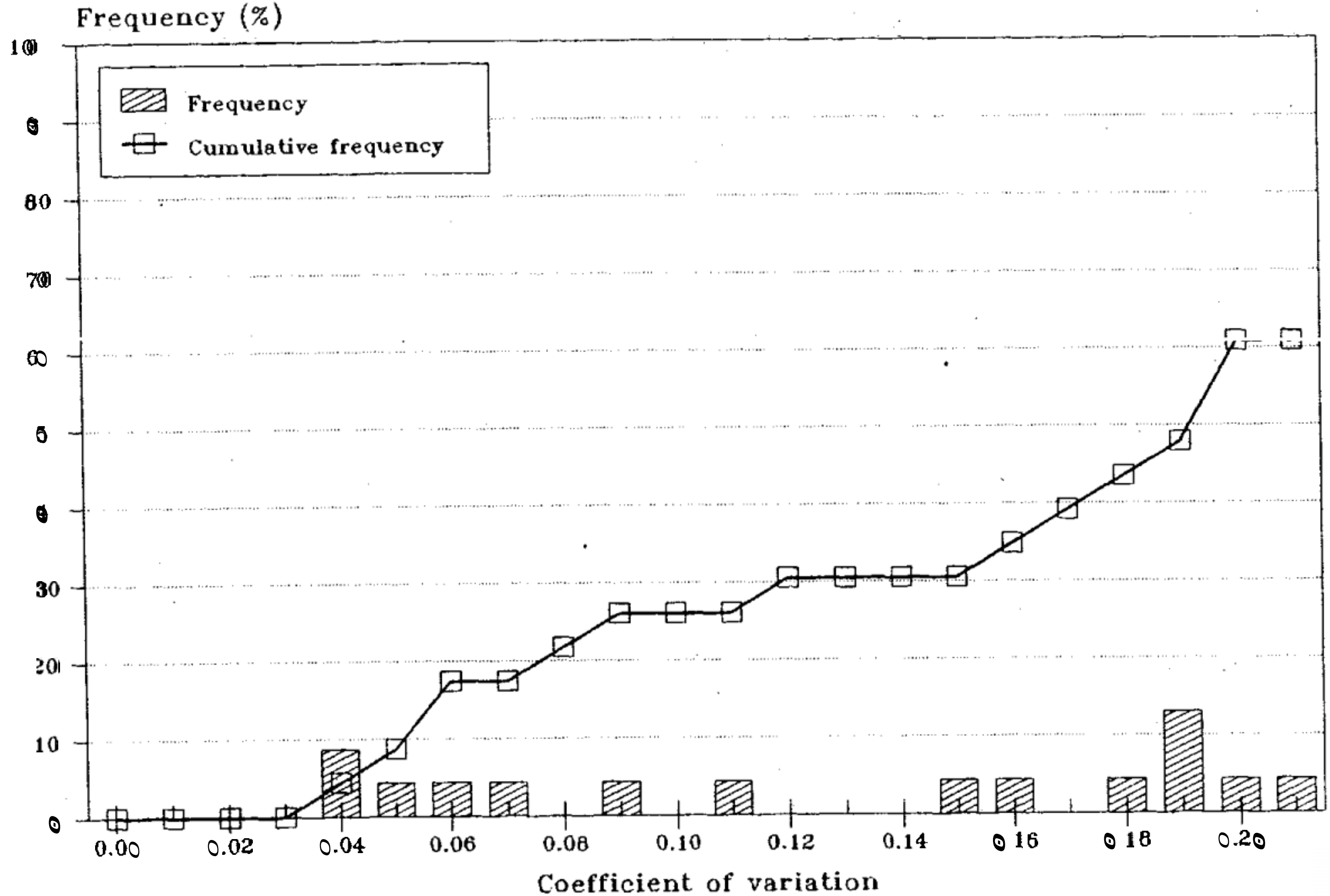
Average CV = 0.185

Kirindi Oya: Distribution of coefficient
of variation of discharge in BC2



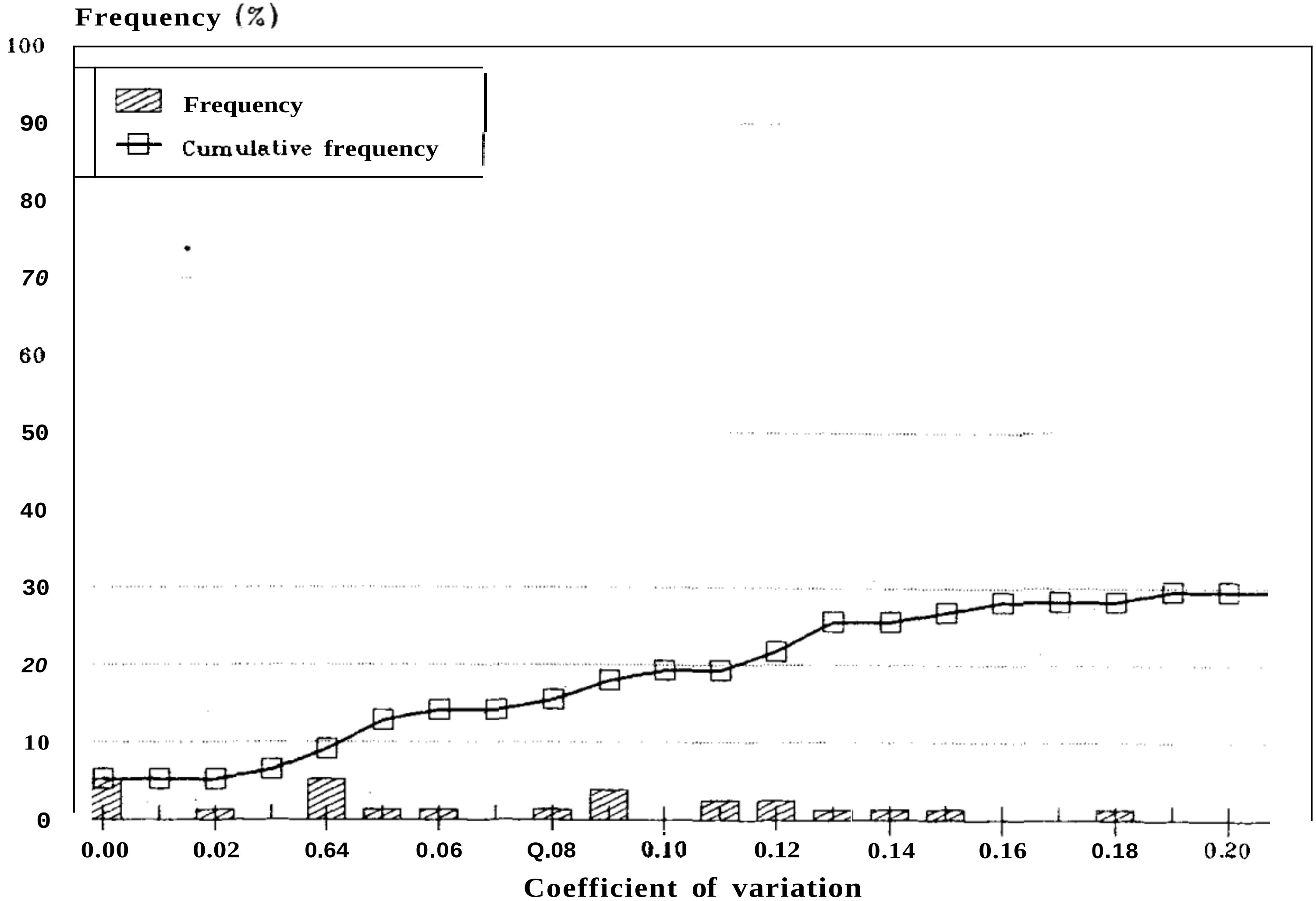
Average CV = 0.159

SDA: Distribution of coefficient of variation of discharge at the headgate



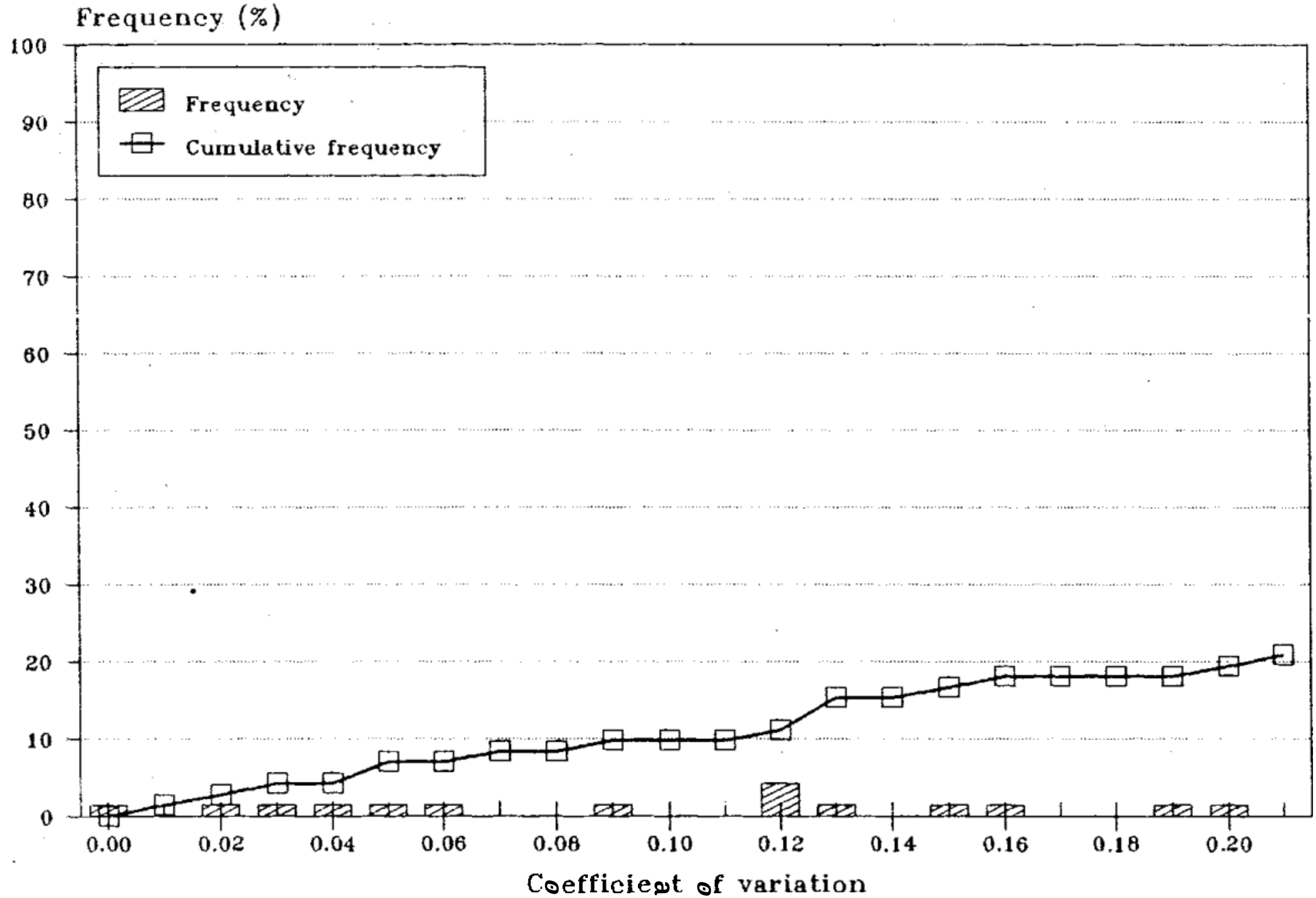
Average CV = 0.189

SDA: Distribution of coefficient of variation of discharge in Lateral B



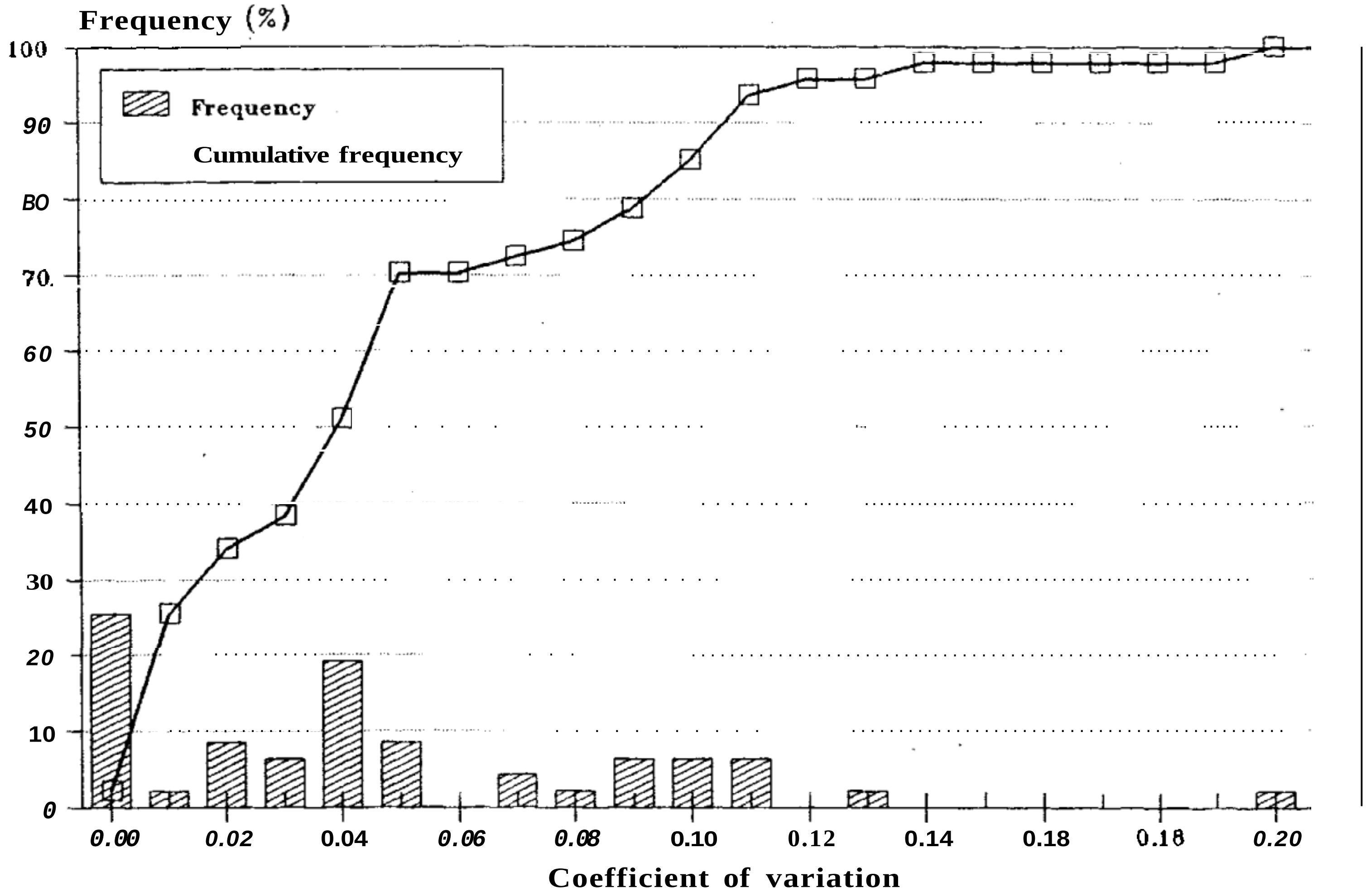
Average CV = 0.401

SDA: Distribution of coefficient of variation of discharge in Lateral G



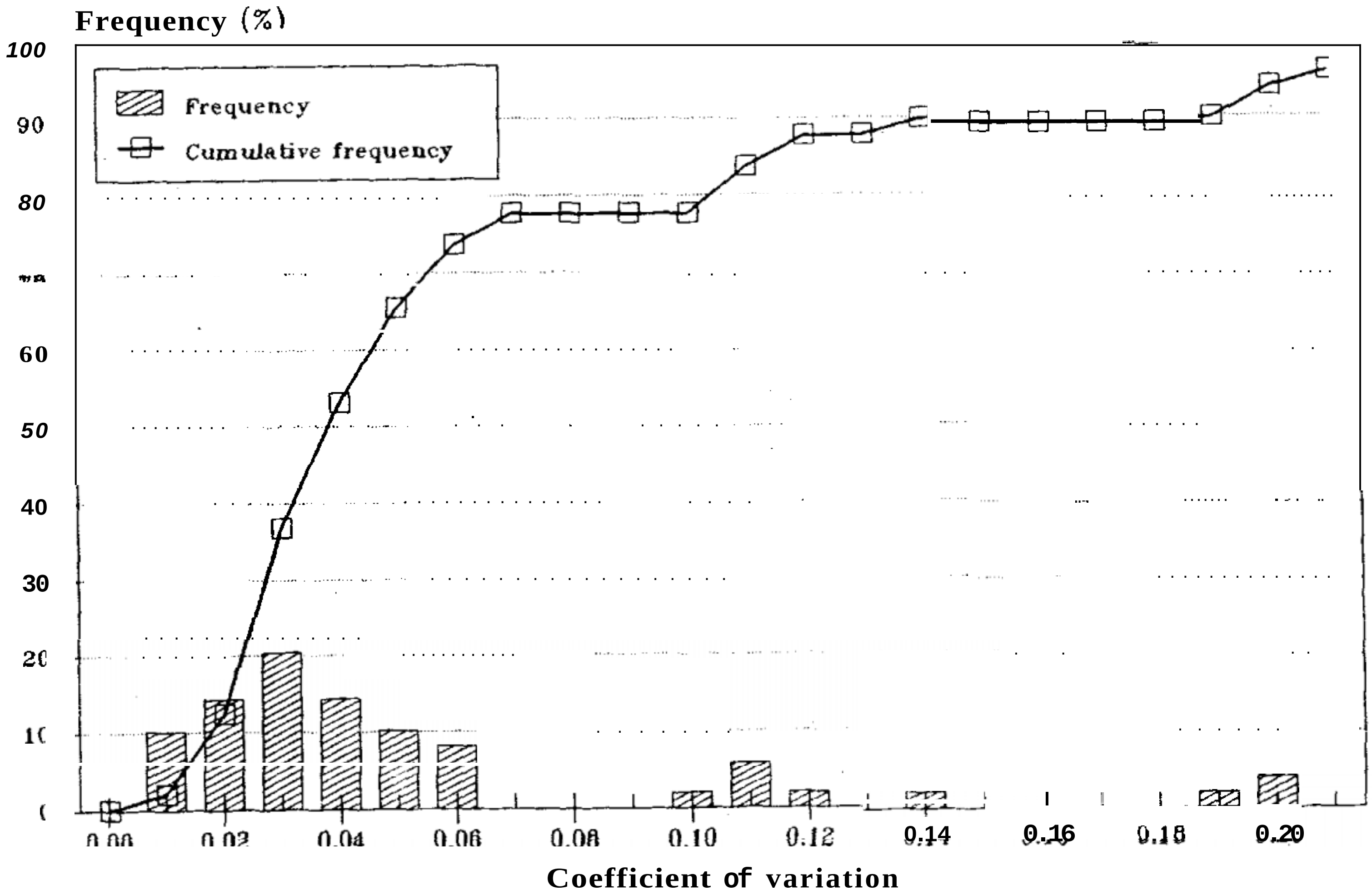
Av CV = 0.887

Rajangana: Distribution of coefficient of variation of discharge in pilot. distributary canal



Average CV ≈ 0.047

Rajangana: Distribution of coefficient of variation of discharge in control distributary canal



Average CV = 0.063