MOBILIZATION OF RESOURCES, SENSITIVITY AND VULNERABILITY IN CANAL OPERATION

DIAGNOSIS & PRELIMINARY ANALYSIS

by

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1. INTRODUCTION: DISTRIBUTION OF EFFORTS FOR OPERATION

To operate an irrigation system, managers need to mobilize resources: human, transportation, hardware and software. These resources are required for the implementation of the changes in the system status, as well as for data collection and treatment to support decision making. Ultimately, resources can also be expressed or converted in terms of money. The amount of resources mobilized by the managers, could be called **'efforts'**.

At first glance, efforts for canal operation, are homogeneously distributed within irrigation schemes or systems. The criteria used to determine the amount of efforts are the area served by the specific canal and/or structure, the number of adjustable structures, the number of farmers, etc.

Increasing water productivity is a major goal for the community. Reducing irrigation financial burden in public budgets is also a necessity. Thus, the question of the cost-effectiveness in operating irrigation schemes is a critical issue. Improved operation procedures have to be promoted. n that sense, it is important to scrutinise the current distribution of efforts along a canal and to compare it with the actual performance. It is also essential to re-evaluate targets of performance, with respect to the environmental and agricultural context in which water distribution takes place. New strategies of mobilization of resources and allocation of efforts could be proposed to account more specifically, for the sensitivity of the irrigation systems and for the vulnerability of the command areas.

The assumption behind the study is that a selective distribution of efforts in operation is the most effective approach. The case study of the Kirindi Oya Irrigation Settlement Project in Sri Lanka (see map in Appendix) is used to illustrate the proposed methodology.

2. A DIVERSE SCHEME: KIRINDI OYA SETTLEMENT PROJECT

The Kirindi Oya Irrigation and Settlement Project (KOISP) is one of the largest agricultural based development programs, implemented in the southern part of the island. This project was completed in 1986. The system consists mainly of four sub-systems: the Old Ellegala irrigation system, the newly developed area under the Right Bank (RB area), the newly developed area under the Left Bank (LB area) and the Bandagiriya system. Each sub-system is treated differently in terms of priorities in the allocation and distribution of water.

2.1 Description of the system

The Old Ellegala Sub-System: The Ellegala sub-system (about 4110 ha) existed prior to the new development under KOISP. It receives water through inter-connected tank systems (5 tanks), and anicut or diversion structure across the Kirindi Oya river. A new feeder canal has also been constructed under the new project, to ensure water to the old anicut and the interconnected tank system.

The Right Bank Area: The Right Bank main canal system includes five sub-administrative units known as tracts. Tracts 1, 2, 5, 6 and 7 have been developed, totalling a command area of 3290 ha.

The Left Bank Area: The Left Bank main canal system includes Tract 1, 2, and part of tract 3 totalling command area of 1835 ha.

The Bandagiriya Sub-System: The Bandagiriya sub-system, 600 ha constructed about 36 years ago, has its own catchment and can now receive additional supply from the new project through the Right Bank main canal.

The Climate: KOISP is located in the south-east quadrant of Sri Lanka. Two seasons: the wet season, *Maha*, (October to February or March); the dry season, *Yala* (April to September). The mean seasonal rainfall for the Kirindi Oya area is 750 mm in *Maha* and 240 mm in *Yala*.

The Crops: During *Maha*, high yielding rice varieties are grown in almost the entire project area. In the dry season, *Yala*, the old areas are usually cultivated with rice. The new areas, are cultivated with rice or left fallow, depending on the availability of water. Some non-rice crops are also grown on limited areas during *Yala*.

2.2 A cascade system open to the sea

Two main characteristics of KOISP are fundamental to understand the hydrological behaviour in the area:

- It is **a cascade system** which is common in Sri Lanka. It implies that run-off, overflow and drainage coming from upstream areas are, for the main part, collected and stored in downstream reservoirs.
- It is **a basin open to the sea** which means, the KOISP is the last water user before the ocean is reached. Hence, any amount of water saving in the project area is a sort of 'true saving'.

2.3 The multiple uses of water

Irrigation water is used for purposes other than seasonal field crops. The multiple uses of water are:

⇒ Domestic consumption (water network for the new areas, recharging of the groundwater in old areas).
⇒ Use of water by the environment (wetland sanctuary, wild life park).
⇒ Bathing facilities in tanks and canals.
⇒ Fishing in downstream lagoons as well as on inland tanks.
⇒ Consumptive use for perennial vegetation (homestead garden and natural trees).

3. DIAGNOSIS OF THE CURRENT SITUATION: THE CASE OF THE RIGHT BANK MAIN CANAL

The RBMC was equipped with an information system in 1991 (IMIS, Rey and et al., 1993). Data collection started for Maha 91/92 (wet season) and has lasted since then. Data is recorded twice a day at every structure along the RB canal. A set of 6 irrigation seasons, between Maha 91/92 and Yala 95, is used for the purpose of this analysis.

3.1 Resource mobilization

As usual for manually operated system, human labour (Gate Operators) is the main component of the resource mobilized for operation. The allocation of efforts is estimated tract per tract. However, tracts 6 and 7 are considered as a single unit of management. Several operators are responsible for each tract: 4 operators for tracts 1and 2; 5 operators for tracts 5 and 3 for tracts 6-7. The area served by each tract

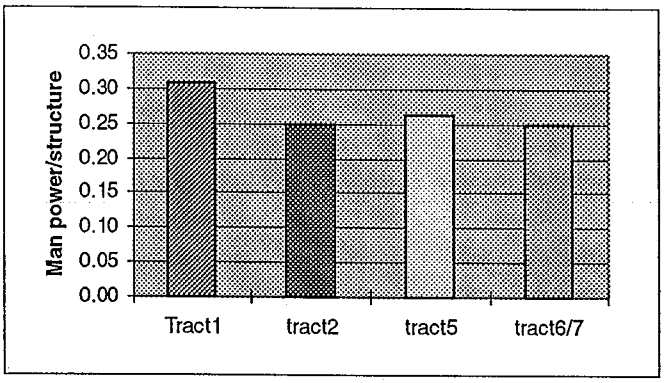
is rather constant (850-1000 ha). Area served by an operator varies between 213 to 300 ha. Density of structure per operator, is also rather constant, between 3.25 in tract 1 and 4 in tracts 2 and 6-7. Table 1 displays some statistics on the allocation of resource and on the equipment. Figure 1 shows the allocation of manpower per structure. This parameter is also rather constant. It varies slightly between 0,25 for tracts 2 and 6-7 to 0.31 for tract 1.

These figures show that, current mobilization of efforts, is somewhat consistent with the area served and with the structure density.

Table 1. Allocation of human resource and equipment

	Number of Gate Operators	Area served (ha)	Area/ Operator (ha)	Number of regulators	Number of offtakes	Structures per operator
TRACT1	4	851	213	3	10	3.25
TRACT 2	4	868	217	6	10	4
TRACT 5	5	1005	200	5	14	3.8
TRACT 6-7	3	896	300	4	8	4

Figure 1. Allocation of efforts per tract (Man Power per Structure)



3.2 Density of operation

Figure 2 plots the number of intervention per gate-regulator, as an average for the 6 seasons. The number of operation along the canal does not vary that much. For tracts 1 and 2, the variation is between 30 and 38 per season. For tract 5, it is higher (mean is 44) and more variable (33 to 52). For tract 6/7, the mean is 38 but the range of variation is high, from 20 to 60.

Table 2 contains some figures on density of operation. It can be seen that the density of operation per operator, is higher for tract 1 (150), than for the others (around 100). The number of operation per offtake decreases from 60 per season for tract 1, to 34 for tract 5. This tendency, is confirmed by the evolution of the number operation per offtake along the canal, as shown in Figure 3. This, obviously, reflects a variation in the quality of operation.

Figure 2. No. of operations per gate-regulator (Average for 6 seasons) - KOISP RBMC

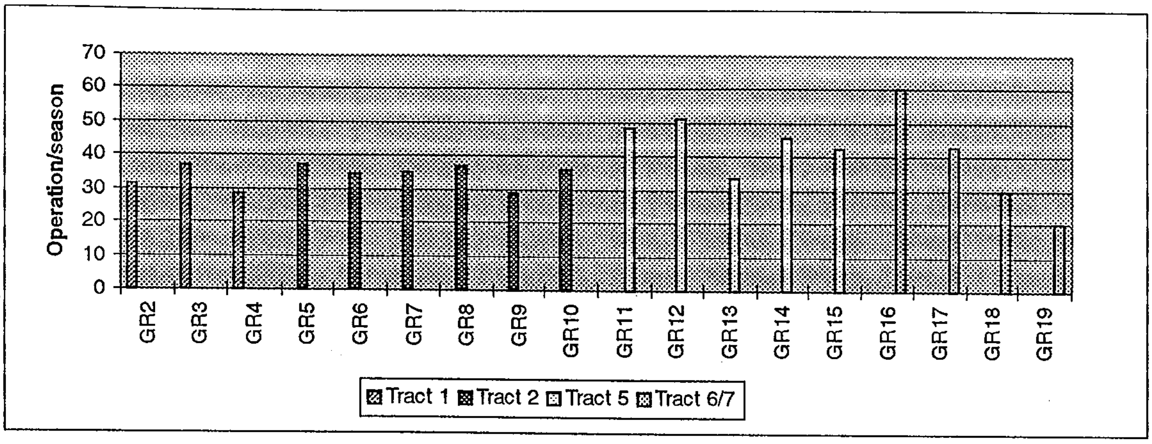
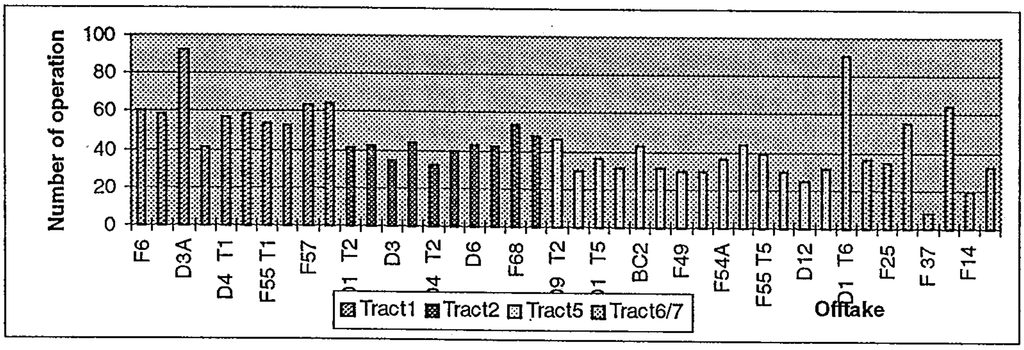


Table 2. Density of operation

	Quantity of operation per offtake	Quantity of operation per gate per regulator	Operations per operator
TRACT1	60	32	150
TRACT 2	42	35	105
TRACT 5	34	44	96
TRACT 6/7	42	38	113

Figure 3. No. of operations per offtake (Average for 6 seasons) - KOISP RBMC



3.3 Current performance in controlling water depth

The control in water depth is plotted in Figure 4. The variable, here, is taken as the standard deviation of the water level upstream each regulator. Control varies from 0.08 for tract 1 to 0.12 for tract 6/7.

Figure 5 plots the variation of water depth at every offtakes along the canal.

Figure 4. Standard deviation of water depth upstream cross-regulators (Average value for 6 seasons) - KOISP RBMC

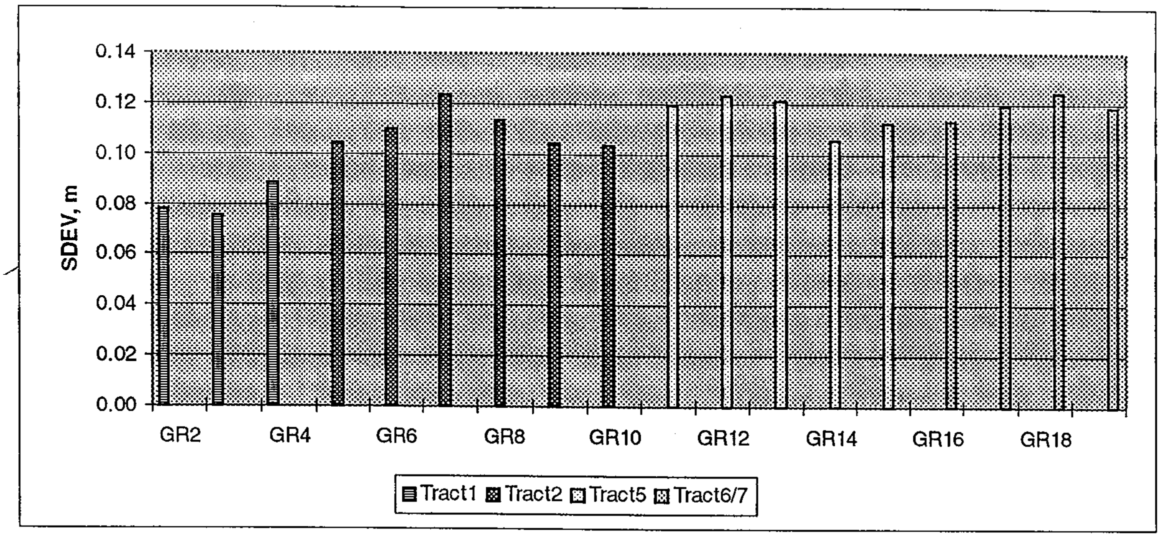
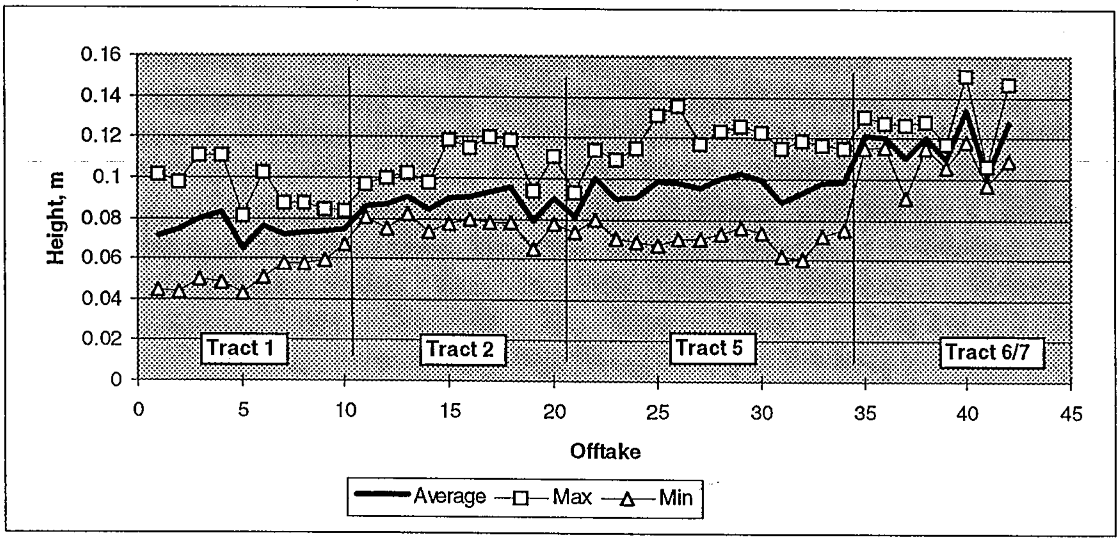


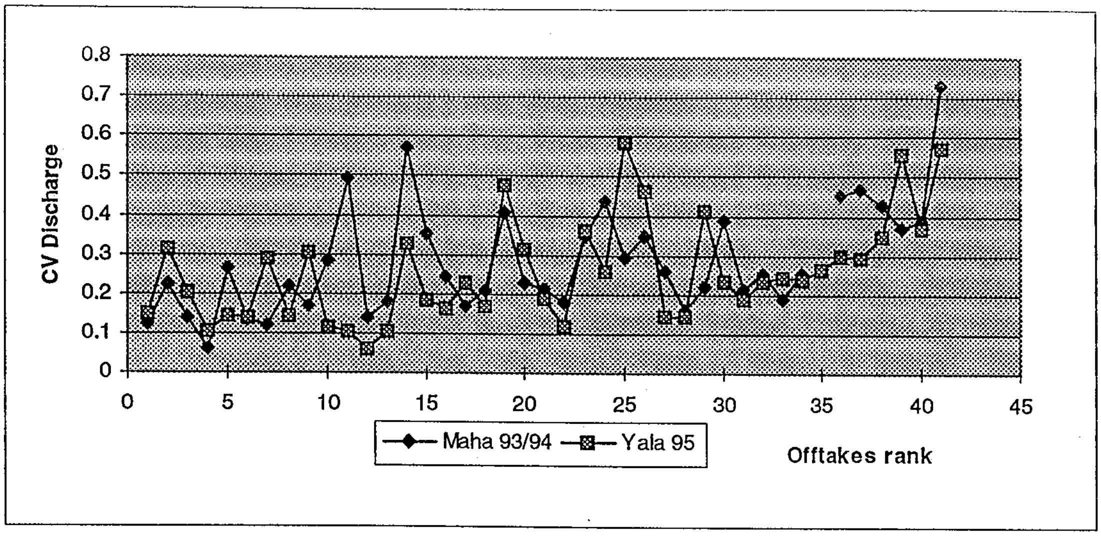
Figure 5. Standard deviation of upstream water level at offtakes (Maximum, Minimum and Average for 6 seasons)



3.4 Performance in controlling deliveries

The coefficient of variation of discharge at delivery points increases from upstream (around 0.2) to downstream (between 0.3 and 0.6), as shown in Figure 6. This constant increase cannot be attributed only to the variation of head as seen in Figure 5 because offtakes are low sensitive. The main contributing reason for this increase is the change in the setting of the structure as shown below.

Figure 6. Discharge variation along the RBMC (Coefficient of Variation)



4. OFFTAKE SENSITIVENESS AND VARIATION OF DISCHARGE

The offtakes in RBMC-KOISP has a low sensitiviness of delivery (about 0.5) (Renault and Hemakumara, 1997). The high variability of discharge as stated in Figure 6 thus cannot be explained by the measured variation of the water depth. This can be established as follows:

By definition, the relative variation of discharge is equal to the product of the sensitiveness of the offtake and the variation of water depth, as shown below:

$$\Delta q / q = S_1 \; \Delta H_{US}$$

Assuming that $\Delta H_{US} = 0.12$, and a sensitiveness of 0.5, the likely variation of discharge, that offtakes should experience, is:

$$\Delta q / q \approx 0.06$$

Actually, offtakes along the Right Bank experience a C.V. (qi) from 0.1 to 0.6. The gap between these values and 0.06 is attributed to the variation of the setting of the offtakes.

5. SENSITIVITY OF CONVEYANCE FOR IRRIGATION SYSTEM

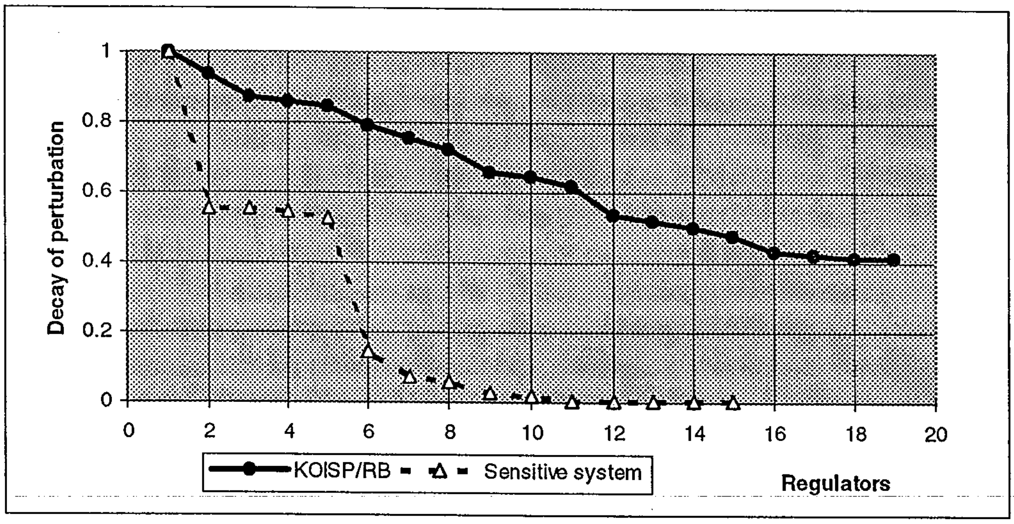
Sensitivity analysis applied to irrigation equipment consists in studying the **reaction of canal components to a perturbation in the input** (discharge, water depth, setting). We define here the sensitivity of conveyance for the irrigation system as the ratio between the perturbation that is propagated and the perturbation that is entering the system. It writes:

$$S = \frac{DQ_{out}}{DQ_{in}}$$

By plotting this indicator, a decay curve of a perturbation generated upstream the system can be defined. It is assumed, implicitly, that the structures are not operated. Systems having high sensitive offtakes tend to absorb the perturbation. Systems having low sensitive offtakes, inversely, let the perturbation continue downwards. KOISP/RB falls in the last category. The decay curve is not steep, as shown in Figure 7. About 40% of the upstream perturbation is still, felt at GR 19, after 27 km.

For the purpose of comparison, we plotted on the same diagram the decay curve obtained for a system having high sensitive offtakes. This system is presented in another paper (Renault and Hemakumara, 1997) (Mahaweli SB/LB). For this system, the decay curve is steep. After the sixth regulator, the perturbation is attenuated at 90% level.

Figure 7. Decay of perturbation along the RBMC canal without operation



6. ACTUAL OFFTAKE OPERATION

To analyse operation in more detail, we selected an important offtake, BC2. It is a branch canal diversion point, located in tract 5, withdrawing approximately 0.8 m3/s (about 10% of the total discharge).

In Figure 8a, parameters of BC2 are plotted for Maha 91/92. This season is somehow representative of what is usually expected. At the beginning of the season, opening of the gate (spindle height) and discharge offtake are set at a high level (0.9 m3/s). This is due to the fact that water requirements for land preparation are higher than for the remaining part of the season. Water level is rather steady during the most part of the season. At the end, however, variations of 0.5 meters are experienced. This is related to the unsteady discharge balance along the canal occurring at the close of the season.

The RBMC system has a high sensitivity to discharge perturbation (see §.5). Upstream variations of discharge, highly influence the balance in downstream reaches. Thus, BC2, located in the downstream part of the canal, is perturbed by all the discharge changes occurring upstream, when gates are closed one by one.

For Maha 92/93, the pattern is different, as shown in Figure 8b. Discharge is regularly increased from 0.8 m3/s at the start of the season, to 1.4 m3/s at the end. No explanation has yet been found for that variation.

7. VULNERABILITY ANALYSIS OF THE KOISP COMMAND AREA

The study of **opportunities and constraints** for each command area, served by an offtake, allow to partition the irrigated domain into units of homogeneous **vulnerability**. A highly vulnerable area is defined as a unit in which impacts and side effects of low quality operation are high. For example, non drained areas are vulnerable to the excess of water (water logging). An area with sensitive and/or high value crops will suffer from any shortage of water. Low vulnerability areas are those in which impacts and consequences of low quality operation are not so great.

The study of the vulnerability distribution, finally, ends up with a better definition of the service of water to users and the level of performance that operation should achieve.

7.1 Recycling of water

A large part of the irrigation command areas of KOISP, are well drained. Thus, drainage is not a partitioning factor. For some areas, drainage water is recycled through intermediate tanks. For other areas, drainage water is lost. The water in irrigation tracts 1and 2 under RB canal are recycled. These tracts are considered much less vulnerable than those pouring directly or indirectly into the sea, i.e., tracts 5 and 6-7.

7.2 Type of crops

Rice, is almost the only crop grown in the area. Past attempts to diversify the cropping pattern have been of little success. However, irrigation managers and agricultural authorities are very aware that less water demanding crops improve water productivity. Other field crops (OFC) have to replace rice during the dry season, in places where water efficiency is low. In KOISP RB, this situation applies for tracts 5, 6 and 7, where the soil is light and percolation is high.

Providing water for rice, is much less demanding in terms of operation that for other field crops. Thus, another factor of partitioning for operation is the type of crops: rice is a crop having a low vulnerability whereas other fields crops are highly vulnerable.

Vulnerability analysis leads to distinguish tracts 5 and 6/7 (high vulnerable) from tracts 1 & 2 (low vulnerable). A map of the lay-out of the scheme and of the vulnerability is given in Appendix.

8. PERSPECTIVES IN INTEGRATING SENSITIVITY AND VULNERABILITY IN RESOURCES MOBILIZATION

The analysis presented here is embryonic. It is planned to use it as a starting point for further discussion with managers and further investigations. A deep analysis should be made to better diagnose the rationale of the use of resources hitherto, before making any recommendations.

However, preliminary results show some convergencies towards a more selective strategy for canal operation. This strategy should be based on the sensitivity of the irrigation system and on the vulnerability of the command areas to operation. On the sensitivity side, the important aspect is that the system has low sensitive offtakes. Thus perturbations are propagated downwards. On the vulnerability side, recycling facilities and crop diversification seems to be the more important factors to take into consideration.

In the lights of these preliminary results, it seems that more effort should be put in the two downstream tracts, 5 and 6/7:

- to better attenuate perturbations coming from the upstream reaches.
- to better cope with the fact that there is no recycling facilities.
- to allow a more flexibility in the delivery for crop diversification.

We must conclude by mentioning that allocation of resources for operation had already been changed in KOISP-RB. This change occurred at the end of 1995 (after the last season considered here). It was essentially meant to save labour in the operation activity. The reduction of labour has, been more or less, shared proportionally. No particular. Number of operators has been reduced from 4 to 2 in tracts 1 and 2, from 5 to 3 for tract 5 and from 3 to 1 in tract 6-7. This new allocation of human resource leave tract 6-7 with only one operator. According to the preliminary result of this analysis, this can lead to lost in the control of the delivery. The effect of this restructuration of effort for operation will be studied carefully for 96 and 97 irrigation seasons particularly in the downstream tracts. By combining the two operational modes, i.e., from 91 to 95 and from 96 to 97, it is expected to derive a better understanding of strategic rules that have to be promoted for a better cost effectiveness of canal operation.

References

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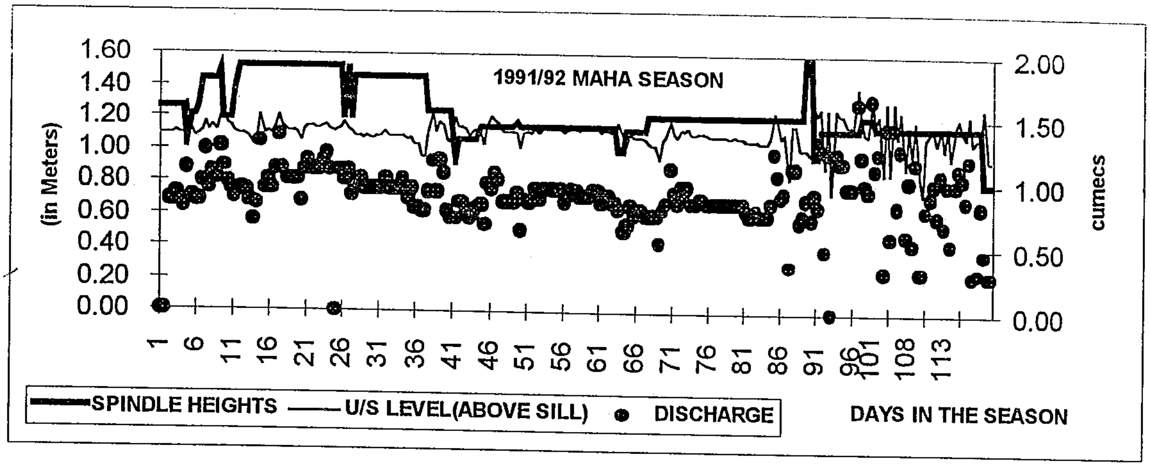

Figure 8.a. Parameters for Offtake BC2 during Maha 91/92.

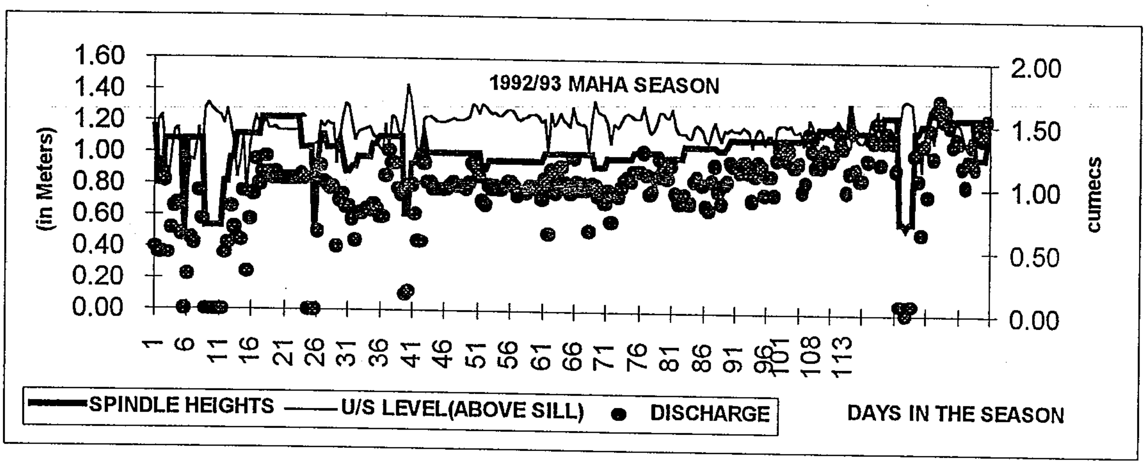

Figure 8.b. Parameters for Offtake BC2 during Maha 92/93.

KIRINDI OYA IRRIGATION & SETTLEMENT PROJECT PROJECT MAP