MODERN TECHNIQUES FOR MANUAL OPERATION OF IRRIGATION CANALS - MALAYSIA (KERIAN)

by

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Abstract

Kerian Irrigation Scheme which has a net paddy area of 23,559 hectares is the third largest granary in Malaysia. The coastal compartments A-D are called Kerian Laut whereas upland compartments E-H are called Kerian Darat. Sixty one percent of irrigation supply is provided by Bukit Merah Reservoir while Bogak Pumphouse supplements supply only in Kerian Laut. The primary canals which are regulated by cross regulators have relatively more steady water levels than secondary and tertiary canals. Due to various factors like overtapping, illegal tapping and inadequate control structures, the water levels in the secondary and tertiary canals are not stable and constant head orifice (CHO) of tertiary canals are not being operated as proper control and measurement structures. From performance assessment carried out, it was found that adequacy, reliability, timeliness and equity of irrigation are generally good. However, average irrigation efficiency was quite low at about 60%. Beside constructing additional control structures and rehabilitate the farm offtakes, the present Irrigation Management Control System (IMCS) also needs to be improved. The IMCS is currently undergoing improvement with more real time data collection, two way communication between field staffs and Control Centre via a computer network and user-friendly irrigation management software. With a Water Optimization Model and proper operation rules being incorporated into the system, irrigation efficiency should improve besides achieving more steady water levels in canals.

1. CONTEXT OF THE SYSTEM

1.1 Physical system layout

Kerian Irrigation Scheme which is located in the North-West of Perak State is the third largest granary in Malaysia with a net paddy area of 23,559 hectares. The scheme is divided into eight compartments, i.e. A to H, and each compartment is further divided into three to four blocks of about 850 hectares each (Please refer Fig.1). Compartments A to D which are located beside the Straits of Malacca are referred to as Kerian Laut. On the other hand, Compartments E to H which are located in the upland region are referred to as Kerian Darat.

1.2 Topography, soil and environment issues

Kerian Laut generally has a rather flat topography where about 70% of the area are below R.L. + 1.22 m. Kerian Darat is more undulating sloping from the highest point of R.L. + 3.96 m at the foot of the Bukit Merah Reservoir towards Bagan Serai town at R.L. + 2.30 m. Kerian Laut consists mostly of marine clay and some organic clay (Compartment D only), whereas Kerian Darat consists mostly of alluvial riverine clay and also some organic clay. The drainage of Kerian Laut is under tidal influence as the spring tide is within the range of R.L. + 1.46 m to 0.76 m. There is this perennial water logging problems in the low lying paddy areas in Kerian Laut due to the main factors below:

i. short duration of 4-5 hours only for drainage during low tides.
ii. non-adherence of planting schedule and absence of water retaining farm ridges and drain bunds making it necessary to maintain the water level in the drain perpetually high.

1.3 Infrastructures and water availability

The main source of water supply is from Bukit Merah Reservoir which provides about 61% of the supply. This is being supplemented by the Bogak Pumphouse with four pumps of 5.1 cumecs each which diverts water from the Kerian River. Two primary canals namely Main Canal and Selinsing Canal convey water from the Bukit Merah Reservoir through 2 intakes of 800 cusecs and 400 cusecs respectively. Main Canal conveys water to Compartments A to F whereas Selinsing Canal supplies only to Compartments G and H. The Bogak Pumphouse pumps water from Kerian River directly into Main Canal at Compartment D and thus supplements supply only for Kerian Laut.

There are altogether 56 km of primary canals, 327 km of secondary canals and 368 km of tertiary canals. The primary and secondary canals are earthen while the tertiary canals are concrete-lined. Water control in the primary canals is managed with cross-regulators with screwdown gates used as undershot structures with side weirs. Offtake structures are of the Constant Head Orifice (CHO) type whereas, farm offtakes are either butterfly-type or guillotine-type. There are about 706 gated irrigation structures and 800 farm offtakes in the scheme. The average canal density is 31.2 m/ha. The scheme also has 580 km of secondary and tertiary drains respectively which discharge into Kerian River, Kurau River or directly into the Straits of Malacca. There are 207 gated drainage structures including 57 Tidal Control Gates in the scheme. In a normal year, the water supply is usually more than sufficient. Only once in about 4-5 years, water shortage may occur during the off-season when there is a drought period. Due to the settlement of the railway embankment cutting through the Bukit Merah Reservoir, the maximum operation level is only +28.50 feet new resulting in a limited active storage of 56 Mm^3 only. There is a proposal to raise the embankment so as to increase the storage by 18 Mm^3 at the design operational level of +30.00 feet.

1.4 Water distribution and control

The Kerian Irrigation Scheme is divided into three irrigation schedules. Schedule One consists of Compartments A, B and C which are located at the end of the Main Canal. Schedule Two consists of Compartments D, E and F located at the upstream of Schedule One and receives supply also from the Main Canal. Schedule Three consists of Compartments G and H and is supplied through Selinsing Canal. Each schedule is staggered 30 days from the earlier schedule. Each schedule is designed to receive 30 days of presaturation supply followed by about 110 days of supplementary supply. The design presaturation module is about 20 mm/day, twice that of the supplementary module. Since most farm offtakes were constructed at ground levels, a lot of overtapping occur especially at the upstream ends of canals. During supplementary periods, it is found to be difficult to maintain Full Supply Levels (FSLs) at design discharges due to overtappings and flatter hydraulic gradients at half the maximum discharges. Inevitably, supplies have to be boosted up above design supplementary rates especially in Kerian Darat where the ground is steeper. Additional intermediate control structures are found to be necessary for stepping up the FSLs during supplementary supply periods for Selinsing Canal and other long and oversized secondary canals.

There are no water users' group in the scheme. The farmers are responsible only for the operation of the farm offtakes. Illegal farm offtakes and overtapping are still rampant. However about 90% of the farmers are members of the Area Farmers' Organization (AFO) through which some of the irrigation problems are communicated to the irrigation agencies. With chains and padlocks used on gated structures, illegal gate operation still happens. Each season an estimated 800 - 900 mm of irrigation ends up as drainage water and so far no recycling of this water has been done. There is a plan to purchase mobile pumps of about 5 cusecs each for water recycling this year. About ten sites have been identified suitable for this form of water recycling scheme. However, meanwhile, some back flow of water from drains with sustained water levels into paddy fields is also a form of drainage water re-use.

2. RATIONALE AND EVALUATION OF IRRIGATION SERVICE

2.1 Characteristics and rationale of irrigation service

The cropping pattern and schedule of irrigation water deliveries to the various compartments are planned according to the three irrigation schedules. The off-season is usually from February to July and the main season from August to January. Due to shortage of labour and slow progress of mechanization especially in Kerian Laut, non-adherence of the cropping schedule is very common and a season may take up to eight months to complete. The amount of irrigation water to be given to each secondary irrigation block is usually guided by the observation of actual field activity progress and field water depth. During the initial stage of supply, the actual amount of irrigation water required usually builds up very slowly due to late start of land preparation/planting by many farmers. However, it is difficult to achieve FSLs at these low flows (less than half of maximum flow rate) and usually much more supplies are given than actually required. The primary reasons for this situation to occur are overtappings, oversized secondary canals and insufficient control structures in certain long and relatively steep canals. Eventually, as the actual water requirement peaks, the match between supply and actual demand usually becomes closer and the Relative Water Supply (RWS) during this period is normally the lowest. However, after full presaturation, the supplementary demand is only half of the presaturation demand and matching of supply and actual demand becomes more difficult again.

Normally, if there are drops in FSLs in the canals, inadequate field water depths or farmers' complaints, the field staffs would respond quickly by requesting additional release from the Control Unit managing Bukit Merah Reservoir. On the other hand, in time of rainfalls, request for reducing supplies are not so spontaneous. Generally, oversupply conditions persist as reflected by the average specific supply of 2,173 mm/season compared to 1,700 mm/season based on design modules and 1,250 mm/season based on basic parameters.

The present water rates levied on the farmers are very low indeed, i.e. about US$1.00 - 4.50 /ha., irrespective of actual water usage by the farmers. However, in order to promote efficient water consumption, there is a need to rationalize the water pricing mechanism through appropriate consideration of relevant factors like:

I. increasing competition on water usage
II. investment, operation and maintenance costs
III. farmers' affordability

2.2 Irrigation performance assessment and evaluation

In the Kerian Irrigation Scheme, two important project objectives are to increase the yield and the cropping intensity. Furthermore, the National Agricultural Policy (1992 - 2010) also stipulates the need to optimize the productivity of water resources in view of the increasing competition from other sectors. To increase yield, adequacy, reliability and timeliness of irrigation will be important aspects to assess and monitor. One of the factors required to increase cropping intensity should be equity in the allocation and distribution of irrigation water. To optimize the productivity of water, water use efficiency should be improved. The performance indicators relevant to assess and monitor are discussed below.

a. <u>Adequacy, reliability and timeliness</u>:

Relative Water Supply (RWS) is defined as the ratio of (Irrigation + Potential Effective Rain) to the Estimated Water Demand. The assessment is carried out on a weekly interval and the weekly RWS values indicate the adequacy of irrigation over the season (please see Fig. 2a). Since no stick gauges have yet been installed to monitor weekly field water depths which would enable the evaluation of effective rainfall, a open water storage model is used to estimate effective rainfall. Fig.2a shows the assessment results for one of the compartments based on this storage model.

To assess reliability of supply, the indicator Supply Reliability (SR) is used which is defined as (1 - WSDFR). Water Supply Deficit Ratio (WSDFR) is defined as the sum of weekly deficits in supply (if any), to total target water supply:

$$WSDFR = \sum_{1}^{N} (WST - WSA) / \sum_{1}^{N} WST$$

where,

WST	-	Target Water Supply
WSA	-	Actual Water Supply
N	-	No. of weeks in a season

A SR value bigger than 70% would indicate that the irrigation supply is reliable for the season, otherwise the supply is considered not reliable.

$$TS = \frac{\text{No. of weeks WSDF} = 0}{\text{Total number of weeks in season}}$$

where, Water Supply Deficit WSDF = @ If (WST > WSA, WST - WSA, 0)

If WST > WSA, then WSDF is considered with the difference between WST and WSA, else, WSDF is assumed as zero.

In other words, it is a ration indicating the percentage of weeks without supply deficit in a season.

These indicators could be assessed down to secondary or tertiary levels but more data would be required. In Kerian Irrigation Scheme, the analysis was done at compartmental level and samples of these results are as shown in Table 1. The average RWS values for the off and main season of 1994 were 1.84 and 2.27 respectively indicating a general adequacy in supply. However, the RWS value for the off season was lower than that for the main season due to a drought period in the earlier season.

Supply reliability was also better at 97.1% during the main season, 1994 as completed to the dry season, 1994, which had a lower SR value of 71.5%. Two compartments, i.e. Compartments A and F had SR of less than 70% in the off season 1994 which were considered not very satisfactory.

Similarly, Timeliness of Supply (TS) for Compartments A and F for the off season of 1994 were rather low at 47.83% and 33.33% respectively probably due to shortage of water. The overall Timeliness of supply for the dry season was only 62.7%. Timeliness of supply was very good in the main season of 1994 at 91.22%.

Table 1. Selection of Performance Indicators, Kerian.

Compartments		Kerian Laut				Kerian Darat				Mean
		A	B	C	D	E	F	G	H	
Off Season 1994	RWS	1.48	2.32	2.17	-	-	1.39	-	-	1.84
	SR	0.492	0.935	0.833	-	-	0.598	-	-	0.715
	COV	0.232				-				0.232
	TS (%)	47.83	85.00	85.00	-	-	33.33	-	-	62.79
	Ea (%)	90.95	66.40	71.95	-	-	89.38	-	-	79.67
	E (%)	72.03	53.17	57.62	-	-	77.08	-	-	64.98
	Yield kg/ha)	3084	3052	3149	-	-	2011	-	-	2824
	WPI (kg/m^3)	0.13	0.11	0.16	-	-	0.14	-	-	0.14
Main Season 1994	RWS	2.55	2.44	2.10	2.53	2.06	-	2.20	1.99	2.27
	SR	0.975	0.952	0.891	1.000	0.984	-	1.000	0.997	0.971
	COV	0.047				0.009				0.028
	TS (%)	90.48	85.71	76.19	100	90.91	-	100	95.24	91.22
	Ea (%)	58.25	59.51	78.91	61.10	61.26	-	65.80	71.65	65.21
	E (%)	46.14	47.65	63.19	50.50	52.83	-	56.17	62.42	54.13
	Yield (kg/ha)	3971	3512	3736	1755	3056	-	2734	3710	3209
	WPI (kg/m^3)	0.17	0.15	0.20	0.07	0.12	-	0.12	0.17	0.14

b. Equity of supply:

Equity of distribution attempts to assess fairness in the allocation of irrigation. It can be assessed by computing and comparing Coefficients of Variation (COV) for SR values from canals in different compartments. In Table 1 however, the comparison of Coefficients of Variation of SR values were made for compartments in Kerian Darat and Kerian Laut. Equity of supply as indicated by a COV value of 0.232 was not very good for Kerian Darat in the drought period of off season, 1994. However, in main season, 1994, equity of supply seemed to be quite good for both Kerian Laut and Kerian Darat (COV = 0.047 and 0.009 respectively). In that season which was a normal year, Kerian Laut was supplemented adequately by Bogak Pumphouse despite the fact that the upstream area Kerian Darat was over supplied.

c. Irrigation Efficiency:

The overall irrigation efficiency (E) is dependent on the conveyance efficiency (Ec), distribution efficiency (Ed) and application efficiency (Ea). While Ec and Ed assess more on the conveyance and distribution aspects as well as quality of operation and maintenance, Ed is largely dependent on farm water management. In the analysis for Table 1, Ec and Ed were assumed as system parameters and the water storage model mentioned was used to evaluate Ea and hence E. It could be seen that the irrigation efficiency in the off season of 1994 at 64.98% was much higher than that for the main season 94 at 54.13% only. However, both were below the design irrigation efficiency of 70% due to overtapping, poor farm water management and little response to rainfall.

2.3 Correlation of agricultural output and irrigation service quality

Water Productivity Index (WPI) is defined as the yield of paddy (kg) as produced by per unit volume of water (m^3). WPI was rather low at 0.14 kg/m^3 for both seasons due to low yield and over supply conditions. To correlate agricultural output and irrigation service quality, a plot of yield versus supply reliability (SR) was done as shown in Fig. 2b. Yields seemed to increase with supply reliability but, in a broad band pattern as expected because other factors like incidence of pests and diseases, care of plants, etc.

3. DIAGNOSIS OF IRRIGATION CANAL SYSTEM

3.1 Characteristics of irrigation canal system

The irrigation system functions as upstream control system. After the intake structures, the two primary canals also have intermediate control structures in the form of cross regulators with screwdown gates used as undershot structures with side weirs. The main purpose of adjustment of these regulators is to achieve FSLs at required discharges. Constant Head Orifice (CHO) and end control structures are provided for primary, secondary and also tertiary canals as control structures. If there are no major improper adjustment of the control structures, supply released from Bukit Merah Reservoir can reach the last compartment within one day. Similarly FSL in the primary canals also become quite steady about one day after each operation.

The farm offtakes consist of two types, i.e. the butterfly valve type and the guillotine type. Those farm offtakes were constructed at ground level thus creating ample opportunity for water wastage because of excessive commands in some of these offtakes. There are also a few thousand illegal farm offtakes tapping directly from secondary and primary canals. Due to rampant overtapping and illegal tapping, water levels fluctuate quite a lot in secondary and tertiary canals. Some of the valves or guillotine gates for the farm offtakes have been abused or removed by farmers in attempts to get more water.

The primary canals are operated in a more coordinated manner and with the help of the cross regulators, the water levels are relatively better controlled and stable. However, Selinsing Canal seems to have difficulty in maintaining FSL during low flows because there is no control structure between chainage 0 m and 7,300 m. In fact, in this stretch of the canal, some tertiary canals have to be connected directly to the primary canal in order to obtain sufficient discharge. A new control structure is now proposed at chainage 3,810 m to step up FSL during low flow.

During heavy rains, there is usually little or no response in cutting supply. There are some storage in both the canals and the paddy fields. However, when there is danger of over spilling or flooding, the supply will then be cut or excess water drained through end controlled structures.

During the commissioning period, additional control structures were constructed in order to achieve FSL during low flow periods. Some more intermediate control structures may be needed especially in long, steep and oversized reaches of secondary canals. Most tertiary CHO are never operated and used properly as control and measurement structures. Gate keepers use their experience and visual observation to determine water adequacy and gate settings and these tertiary CHO are operated like single gated structures.

In order to stabilize the FSL in the secondary canals and to operate tertiary CHO as control and measurement structures, the following actions are proposed:

(1) Rehabilitate the farm offtakes with proper gates at a command of (design head + 6").
(2) Remove all unjustified illegal farm offtakes.
(3) Additional intermediate control structures for secondary canals with long, steep or oversized reaches.
(4) Reconstruct the secondary and tertiary drain bunds for retaining irrigation.
(5) Construct intermediate and end control structures for long and steep secondary/tertiary drains to reduce water loss.
(6) Secondary canals which repeatedly cannot achieve FSL due to excessive over tapping will be supplied in weekly rotation after the presaturation period.

4. DESIGN OF CONTROL TECHNIQUES

An irrigation management control system is being proposed to carry out the following functions:

(1) to assess available water resources, i.e. rainfall, reservoir storage and available streamflow of Kerian River (near Bogak Pumphouse).
(2) to assess crop water requirements and field storage capacity.
(3) to determine discharge allocation to main and secondary canals, gate settings of control structures based on a water optimization model and convey messages to those responsible.
(4) to monitor actual flows and FSLs in canals and structures for fine tuning, further adjustment and performance assessment.

4.1 Hardware configuration

A new telemetric system is proposed to collect real time rainfall, water level, gate openings of important structures, pan evaporation and etc. The computer/workstation responsible to scan and monitor all real time data is to be linked to a main server in the Control Centre. The main server is also linked to other workstations located at Farmers' Development Centres (FDC), Bogak Pumphouse and the District Engineer's Office itself where the Irrigation Inspectors, Pumphouse Operators and Irrigation Control Unit are stationed respectively. The whole computer system will form a Wide Area Network (WAN) which will allow two way real time communication of data. All data are stored in the main server in the Control Centre. The operation staffs at remote offices like FDC and Bogak Pumphouse can also communicate with the Control Centre via VHF radio channels.

4.2 Data acquisition and transmission

a. Water Resources Data:

Water resources data consist of rainfall, reservoir water level and Kerian River water level at Bogak Pumphouse. All these data are collected by automatic telemetric stations and transmitted back to the Control Centre.

b. Crop Water Requirement and Field Storage Capacity:

To determine crop water requirement, data required are field activity progress, agronomic practices, field water depth, pan evaporation, feedback of actual discharges and pumping. The first three types of data are collected manually once in a week and input at the remote workstations before 8.00 am every Wednesday. The present manual pan evaporation stations are proposed to be converted to automatic telemetric recorders. Discharges and water level data for main structures like intakes for primary canals, regulators and pumphouse are monitored by telemetric stations. For other structures, the data are collected manually twice daily.

4.3 Data analysis and operation decision

The irrigation management program residing in a workstation at the Control Center will access the main server for data and carry out analysis to determine the daily water allocation for each secondary block based on the simple water balance equation as below:

$D2 = D1 + I + Re - ET - SP$ where:

D2 and D1	are the final and initial water depths (mm)
I	is amount of irrigation (mm)
Re	is effective rainfall (mm)
ET	is evapotranspiration (mm)
SP	is sum of seepage and percolation (mm)

Re is evaluated using a series of empirical coefficients C1, C2 ... for different ranges of D1, rainfall and storage depths

The water allocation to each secondary block will be based on the following criteria:

(1) If D2 is < minimum water depth (about 50 mm), presaturation duty will be given.
(2) If D2 is > minimum water depth but < Desirable Water Depth for the corresponding crop stage, supplementary duty will be given.
(3) If D2 is > Desirable Water Depth, only half or two third of the supplementary duty will be given during wet and dry season respectively.
(4) Every week, the measured water depth will be used on Wednesday in place of computed D2 for water allocation purpose.
(5) During supplementary supply stage, if FSL drops in any secondary canals due to excessive tappings, the operation and monitoring efforts will be stepped up in these secondary blocks. If excessive tappings continue, these blocks will be supplied only in weekly rotations.
(6) The irrigation management software will be run at 2.30 pm daily for allocation decision and operation at about 3.30 pm. Any rainfall more than 50 mm occurring after 3.00 pm in any secondary blocks will require the irrigation management software to be run again at 8.30 am the next morning for water allocation adjustment. The adjustment of gates for relevant structures will be carried out about 9.00 am if necessary.

4.4 Operation orders transmission

Allocation decision output after being vetted by the Control Unit will be e-mailed to the FDC and Pumphouse. Any negotiation or clarification about water allocation will be communicated through VHF radio.

5. PRACTICAL IMPLEMENTATION

The Kerian Irrigation Project will be allocated about US$ 1.1 million in the Seven Malaysia Plan to implement the proposed Irrigation Management Control System (IMCS) and also automation of some important major structures. For a start, an irrigation block (about 1000 hectares) consisting of about 5 secondary blocks will be selected as a pilot block to be tested with the proposed IMCS.

Before the test running of the IMCS, all the operation staffs will be given training on the operation rationale of the IMCS as well as the various procedures that they have to follow, e.g., collection of data. In the initial stage, field water depths have to be taken daily. This will enable the fine tuning of the various parameters and algorithms assumed in the water optimization model like effective rainfall coefficients, storage capacity, conveyance and application efficiencies and so on. A lot of field feedbacks on water levels, adequacy and equity are required. Through these feedbacks and interaction, the Control Centre can not only fine tune the operation rules as discussed in para no.4 but also improve the overall reliability of the IMCS. Additional modules may have to be added to handle unexpected events like bund breaches, gate failures and flooding, for instance. Meanwhile, the District Engineer's office will also be allocated US$ 140,000.00 to organize farmers into canal based Water Users' Groups. The farmers will be trained in proper farm water management techniques in order to support the proposed IMCS.

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