

# SYSTEM-WIDE WATER MANAGEMENT IN THE DAN HOAI IRRIGATION SCHEME, VIETNAM

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## ABSTRACT

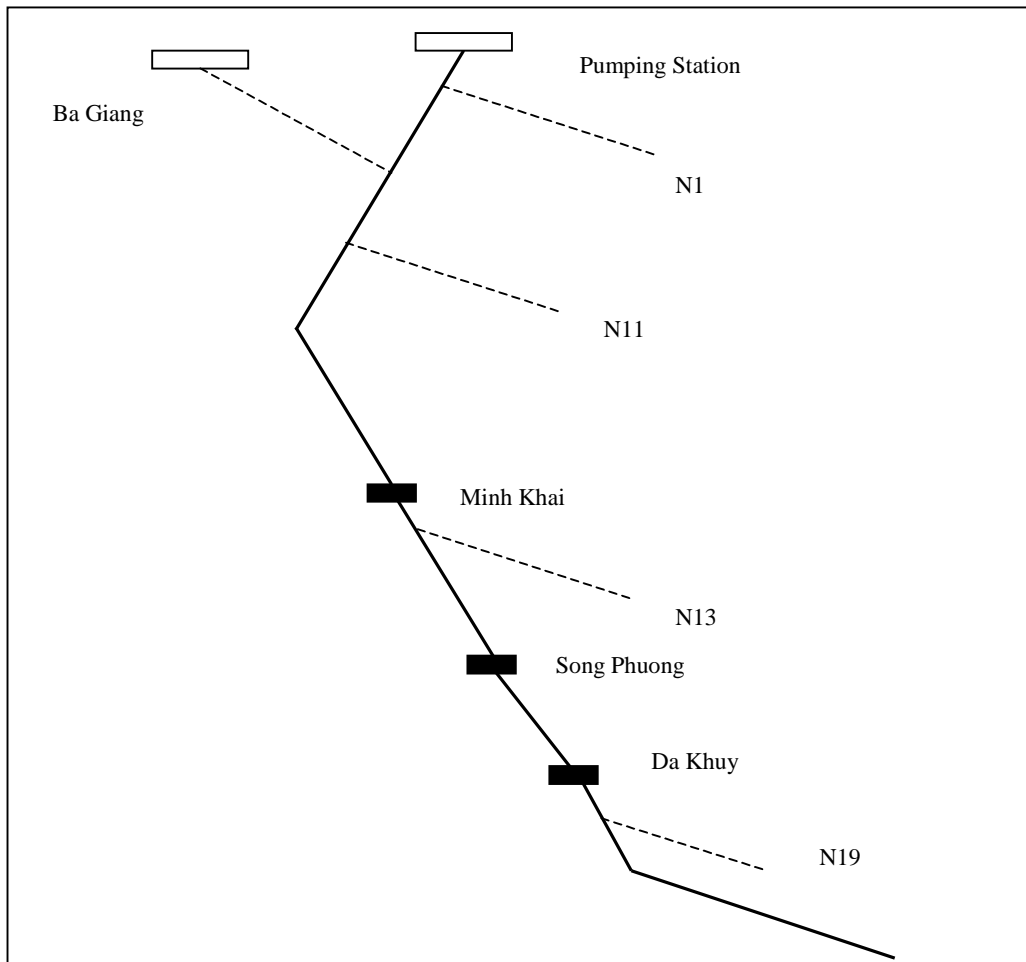
A process of investigation and intervention in the technical operation of the irrigation delivery system was applied in the Dan Hoai Irrigation System, Vietnam. The process involved a GPS based survey of existing infrastructure, calibration of irrigation control structures and implementation of the operation computer model IMSOP (Irrigation Main System Operation). The computer model was used to assist with the operation, retrospective analysis of the system performance, monitoring existing operation and simulation of alternate operational scenarios of which one was subsequently trialled in the field. The retrospective operational analysis in Dan Hoai suggests a consistent under supply of water in the system. The overall distribution of irrigation water in the system is also very inequitable with some canals over supplying and some others under supplying water. Average seasonal supply ratios (actual supply/water demand) ranged between 0.76 and 1.23 during spring 2001 and varied between 0.76 and 0.96 during spring 2002. The field trialled operation scenario consisted of irrigating the entire system using continuous flow simulated by IMSOP model. A post-evaluation of the field trial was conducted by monitoring the flow data at different points in the canal showing a more equitable distribution.

## INTRODUCTION

The Red River Delta (RRD) is the centre of all economic activity in the northern Vietnam, where the majority of the region's population is concentrated. The delta supports nearly half the country's rice production. Irrigation systems in Red River Delta of Vietnam rely heavily on pumping (80% of 850 000 ha) for the provision of irrigation and drainage services. This is achieved by some 1700 pumping stations and more than 7500 pump units. The performance of these systems is rather disappointing. Moreover, the irrigation and drainage of RRD requires high usage of electricity. A research project was undertaken in the Dan Hoai irrigation scheme Vietnam, from 1998 to 2003 between Australian and Vietnamese researchers to investigate and improve the operational performance of the system. The project focused on the application of computer modelling to guide the operation of the irrigation system within the framework of existing institutional arrangements. This paper describes the modelling analysis and field implementation process carried out in the system to improve the operational performance.

## THE DAN HOAI SYSTEM

The Dan Hoai system is located 25 km from Hanoi. The main canal is 23.5 km long and has three cross-regulators to control water levels. In Dan Hoai (**Figure 1**) 15 km of the 23.5 km long main channel have been recently rehabilitated and lined. The scheme supplies water to some 8 000 ha of agricultural land where rice is the principal crop. There are 2 main sources of water to Dan Hoai's main irrigation channel: The Dan Hoai pumping station and the Ba Giang intake sluice. The Dan Hoai pumping station has been in use since 1962 and Ba Giang sluice became operational in 1993. The lowest design water level at the intake basin is +3.05 m and the highest at the channel headwork is +9.00 m. The pumping station in Dan Hoai consisted of 5 low head pumps giving a nominal discharge of 10 m<sup>3</sup>/s. The Ba Giang intake sluice was designed for an upstream water level of +12.70 m and with a downstream water level at +8.90m, giving a design discharge of 12 m<sup>3</sup>/s. If the water level in the Red River (at the intake basin) is higher than +10.70 m, the pumping station shuts down even if there is a need for irrigation in the field. The Ba Giang intake sluice consists of two gates (upper and lower) which are alternatively operated according to the river level. This culvert is mainly opened from June to September during the summer cropping season when the water level in the Red River at this culvert is above 8.9 m. Normally, during this season the pumping station does not operate. If the water level in the river is very low, the pumping station will also operate simultaneously to meet the gap in supply



**Figure 1 Schematic of Dan Hoai system**

There are 3 cross regulators, 42 bridges, 77 large offtakes with varying diameters (20-80 cm) and around 80 small offtakes in the whole system. The system operation is organized through 5 substations under the Dan Hoai Irrigation Company. Contracts for irrigation supply are drawn up between the substation and the agricultural cooperatives, based on cropping plans and assessed area. In spring, during land soaking and land preparation - the period of highest water demand - the company operates all pumps for about 70% of the time and supplies water continuously for 28 days. There is an order of precedence for supply, starting at the head of the system, and a rotational irrigation schedule is practiced between offtakes. After the land soaking period, the canal is operated on a weekly rotation of 6 days supply and 1 day shut down.

### **THE IMSOP MODEL**

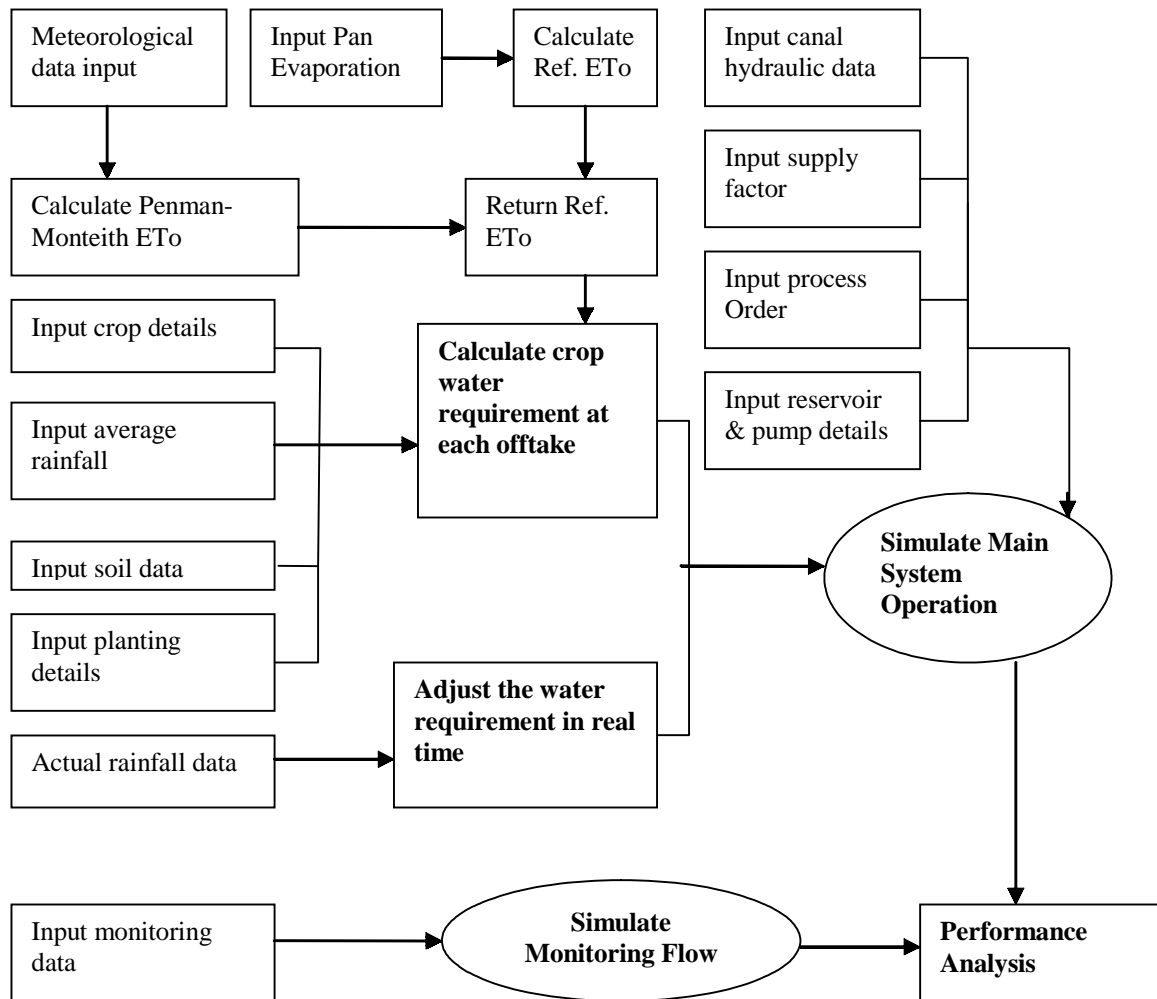
The Irrigation Main System Operation (IMSOP) is a steady-state hydraulic model (**Figure 2**) that simulates the operation of the main canal, secondary canal and pumping stations in an irrigation system (Vlotman and Malano, 1987, Turrall et al 2002, George et al 2003). The model is based on a Graphical User Interface (GUI) built on Visual Basic 6. A Vietnamese version of the software was developed and is available for use by Irrigation Management Company (IMC) staff.

The model calculates reference crop evapotranspiration, using weather station data or using pan evaporation depending on data availability. IMSOP determines steady uniform flow demand in the channel network on the basis of accumulated off-take demands and transmission losses. Calculation of water demand at defined offtakes is based on the cropping pattern and soil type. The water demand calculation for rice includes a deep percolation term which depends on the soil's permeability. Flows are then accumulated, starting at the downstream end of the system, to determine the gross water requirements at each system node and at the head works after accounting for the losses and inflows to the canal network. The model also has the capability to estimate the pumping requirement to meet the irrigation demand, based on the input data on

pumping efficiency and discharge. The most important feature of IMSOP is that it includes a monitoring module that enables the comparison of actual supply and required demand, and can be used to calculate relevant performance indicators of operation and management. The model also enables the user to define service areas within the system and calculate their individual water balance.

The IMSOP model can be used in three ways (Turrall et al 1998):

1. To assess historical performance of the irrigation system, comparing simulated water demand with monitoring data
2. To simulate and analyze alternative operational scenarios to enhance system operational performance
3. To assist system operation in near real-time.



**Figure 2 Schematic diagram of IMSOP model**

The model relies on the schematic of the irrigation system in the form of a network diagram to describe the system infrastructure and simulate the system's operation. The schematic of the Dan Hoai model includes main, sub-main and secondary canals. Individual tertiary canals are represented as canal offtakes. The Dan Hoai model comprises 84 nodes including:

- \* 2 confluence nodes
- \* 4 monitoring points
- \* 3 cross regulators
- \* 1 pump node
- \* 98 off-takes.

## MONITORING AND MODELING PROCESS

Data collection for the application of the model was carried out in the first two years of the project. Cropping areas were monitored on a seasonal basis, by conducting farmer interviews to determine the proportion of different crops planted in each off-take and to determine the planting dates of each crop. Discharge measurement tests were also conducted to determine the performance of 5 pumps at Dan Hoai main pumping station. The implementation of IMSOP requires a full survey of hydraulic facilities and rating of key irrigation control structures. All significant off-takes, regulators and monitoring points were calibrated to develop a head, discharge and gate opening relationship for each individual structure. Manual flow monitoring was initiated at the start of the project by installing automatic capacitance water level recorders at all the monitoring points to obtain continuous records of flow depths. Routine flow monitoring is carried out as follows:

1. Recording of pumping hours to estimate total supply volumes
2. Flow measurement at cross regulators and large secondary canals by measuring the upstream and downstream water levels, gate openings and duration of flow through these structures
3. Measurement of inflow through Ba Giang sluice by reading the upstream and downstream water levels, gate openings and duration of flow.

An automatic weather station was also installed to collect weather data to input into the IMSOP model to estimate the reference evapotranspiration using the Penman-Monteith approach.

The following series of processes took place during the diagnostic and implementation stages of the project (George et al 2003):

- \* Survey of canals and hydraulic structures
- \* Calibration of off-takes and water control structures
- \* Calibration of Ba Giang gate and inclusion into the model
- \* Survey of planned crop area, actual crop area and planting dates for each service area
- \* Flow monitoring in the main canal and cross regulators
- \* Computer simulation and retrospective analysis of the system
- \* Operation modelling to establish alternate operational regimes to provide equitable and effective service
- \* Field trial of alternate scenarios.

### Supply - demand analysis

Two years of comprehensive monitoring of system operation, involving the two main cropping seasons in Northern Vietnam, allowed the calculation of actual water supply to sub-areas within the system and assessment of the operational performance of the system. In this process, the seasonal irrigation demand of the system was estimated using IMSOP for the water years 2000, 2001 and 2002, and then compared with flow monitoring data to understand the shortcomings of the existing operation.

**Table 1 Comparison of supply-demand ratio in 2000, 2001, and 2002**

S. No.	Monitoring Location	Spring 2000	Autumn 2000	Spring 2001	Autumn 2001	Spring 2002
1	Pumping Station	0.85		1.09		0.76
2	N2	0.86	1.44	1.23	1.41	
3	Minh Khai	0.79	1.03	0.93	0.71	0.84
4	N1	0.79	0.70	0.76	0.77	0.96
5	N11	0.93	0.90	0.83	0.80	0.81
	<b>Average</b>	0.84	1.02	0.97	0.92	0.84
	<b>CV</b>	0.07	0.31	0.20	0.35	0.11

In spring 2000, the seasonal demand exceeded supply - 40.9 million m<sup>3</sup> were pumped from the main pumping station to meet a demand of 48.04 million m<sup>3</sup>. The supply-demand ratio at the Minh Khai cross regulator and secondary canals N1 and N11 show that the whole system is undersupplied (**Table 1**). In spring 2001, the quantity supplied from the pumping station exceeded the required demand, but the supply

was found to be less than demand in all the monitoring points except for the N2 canal. This analysis established that there were significant shortcomings in the operation of the system. The supply-demand analysis for the spring 2002 season shows that the whole system is undersupplied. The supply-demand ratio was found to vary from 0.76 to 0.96.

The comparison of supply and demand during autumn season of 2000 and 2001 shows that there is consistent oversupply in the N2 secondary canal which is close to the Ba Giang sluice. The coefficient of variation between supply-demand ratios was estimated as 0.31 and 0.35 during these two years and significantly higher than for other seasons which rely less on water supplied by the pumping station.

Retrospective operational analysis in Dan Hoai suggests a consistent under supply of water in the system. The overall distribution in the system is also very uneven with some canals being over supplied and some canals under supplied. The inequity in distribution can be traced to problems with the hydraulic infrastructure such as channel capacity, bank height, the number of illegal offtakes in the main and secondary canals and malfunctioning of tertiary off-take gates. Moreover, the capacities of cross regulators are insufficient to pass peak demand flows to the lower parts of the system.

### **Modelling and field trial of alternative operational scenarios**

Alternative operational rules were simulated using IMSOP with the aim of improving equity of supply to meet the level of crop water demand. Project staff held extensive discussions with IMC staff, research staff and other stakeholders, including farmers groups, to explore options for changing the operation of the system in order to improve the system performance. Based on these discussions three different scenarios were simulated and analysed using the model. The scenarios selected were:

- \* Continuous flow irrigation in the entire system
- \* Irrigating 2-block 4-day rotation (2B-4D)
- \* Irrigating 2-block 7-day rotation (2B-7D)

The advantage of rotational water supply is that water can be delivered to discrete blocks, allowing parts of the system to be shut-down thus simplifying the operation and improving clarity. The service area was divided into two operational zones:

- \* Zone 1 comprises the upper half of the irrigation system from the pumping station to the Minh Khai cross regulator
- \* Zone 2 comprises the area from Minh Khai to the end of the main channel.

Various combinations of continuous flow and operational zones (2B-4D and 2B-7D) were investigated over a range of assumed tertiary efficiencies. Under a 2B-4D rotational schedule each zone is irrigated for 2 days so that irrigation of the whole system can be fully supplied in 4 days. Here a supply ratio (SR) of two was used for each zone given that water is supplied for 2 days in a 4-day irrigation cycle. After calculating the irrigation requirement for each service area, the flow required at each regulator was estimated and the gate opening at each cross regulator was then determined from previously calibrated discharge-depth-gate opening relationships.

The modelling results revealed that:

1. The capacity of the main canal is not sufficient to meet the peak requirement during land preparation and towards the flowering period, if the whole system is irrigated continuously. Under this scenario, the water level at the Minh Khai cross-regulator should be kept at 8.65 to 8.8m to irrigate the upper zone, causing inequity of water distribution in Zone 2 due to insufficient head.
2. When the Minh Khai regulator is closed to raise the water level upstream, most of the off-takes at low elevation should be closed to provide sufficient head to lift water upstream. However, many of the off-take structures upstream of the regulator cannot be shutdown due to poor condition.
3. Capacity of the main canal and major secondaries like N1 and N11 to meet the peak flow requirement restricted the adoption of any rotational schedule (2B-4D, 2B-7D).

4. The difference between actual pumping capacity and design pumping capacity is estimated as 35 to 45 %. Therefore, the pumps do not have sufficient water supply capacity to adopt any long-term rotational schedule.

The capacity constraints of the main canal to meet the peak water requirement restricted the use of long term rotational options. The modelling results also reveal shortcomings in the design criteria utilised in the recent upgrade of the canal. Capacity constraints and inadequate hydraulic control severely reduce the ability to improve the level of service provision to irrigators.

Currently, the system is operated on a rotational schedule with the main canal running continuously for 6 days a week and rotating the supply to the secondary canals and offtakes. After discussions with company staff and given the constraints imposed by the system hydraulic infrastructure, it was decided to select a single scenario consisting of irrigating according to IMSOP modelled operation based on the existing operational rules. The selected rules were field-trialled in the spring season 2003 (March 2003).

**Table 2 Supply-demand ratio during field trial of alternate scenarios**

<b>Monitoring station</b>	<b>Supply-Demand Ratio</b>
Pumping Station	1.18
N1	1.13
N2	1.28
N5	1.30
N7	1.36
N9	1.12
N13	1.03
N15	1.58
<b>AVERAGE</b>	1.24
<b>CV</b>	0.13

The IMSOP water requirements were determined for each off-take with a range of assumed tertiary efficiencies, and based on this, the pumping requirement were estimated. An operation schedule was prepared for one week which consisted of running the main canal continuously and rotating the secondary canals and offtakes. The schedule was prepared by considering the size and elevation of the offtakes. During the trial, flow data was monitored and collected at flow measuring stations three times a day (7h, 11h, and 17h) during the entire trial period. Gate openings were adjusted twice a day based on the head difference at each gate. The analysis of field data shows a more equitable distribution of water in the system. Supply satisfied the demand at all monitoring points with ratio ranging from 1.03 to 1.58 (**Table 2**). The trial convinced the IMC staff of the advantages of monitoring the actual flow throughout canals and adjusting the gates to irrigate the crops to meet the crop water demand.

As a result of the modelling study and subsequent field trials the following operational rules were proposed for the system:

1. The zone downstream of the Minh Khai cross regulator should be irrigated first and supply to secondary canals within this zone should be rotated.
2. N1 and N11 secondary canals should be supplied water continuously from the main canal and supply to offtakes on these canals should be rotated.
3. While irrigating upstream of the Minh Khai cross regulator, the operation of the direct off-takes on the main canal must be rotated, first supplying the off-takes at low elevation which should later be closed to irrigate the higher land.

## **SUMMARY AND CONCLUSION**

The steady-state hydraulic model IMSOP was applied to Dan Hoai irrigation scheme, Vietnam to study the shortcomings of the current operation and to design and evaluate alternative operational rules. The process involved the implementation of the computer model to simulate the operation, retrospective analysis of the system operation, monitoring existing operation and field trial of alternative operational rules.

The retrospective analysis of the system was carried out for five seasons over three years. This analysis showed large deviations between supply and demand with a consistent under supply of water in the system. The overall supply-demand ratio varied between 0.79 and 0.93 in Spring 2000, 0.76 and 1.23 in Spring 2001 and 0.76 and 0.96 during Spring 2002. The study also revealed that the highly inequitable distribution could be traced to inadequate channel capacity and hydraulic control, the large number of illegal offtakes in the main and secondary canals and malfunctioning of tertiary off-take gates.

Based on the discussion with company staff, a single scenario consisting of IMSOP scheduled flows following the existing operation rules was selected and field-trialled in the 2003 Spring season. The analysis of the field data shows a more equitable distribution of water in the system with an average supply demand of 1.24.

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