チャオプラヤデルタ上流東岸域における水配分計画と実際の水利施設操作の改善

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Improvement of Water Allocation Planning and Practical Operation in the Upper East Bank of the Chao Phraya Delta

-Activities under the Modernization of Water Management System Project in Thailand-

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Contents

I Introduction

Agriculture is one of the main industries in Thailand. The Thai Government clearly stated in the Eighth Agricultural Development Plan (MOAC, 1998) that strengthening Thailand's international competitive position through production of high valued and diversified products and effective utilization of natural resources for sustainable agriculture were the main subjects of the plan. The crop diversification policy (Siriluck et al., 2000) is implemented nationwide, especially in the Chao Phraya Delta. However, due to irrigation water shortages, limitation of land, cost increases and environmental problems, it is necessary to develop irrigation water resources in the dry season through more efficient water management.

The Chao Phraya Delta is one of the greatest rice granaries in the Asian monsoon area. The Delta's farming and water management have changed drastically with the Greater Chao Phraya Project

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(RID, 1957, Kaida, 1975, Takaya, 1980 and 1982, Steve, 1995). The original purpose of the project was for supplementary irrigation during the rainy season. At present, the project's function has extended to irrigation in the dry season, domestic water supply and so on.

Recently, water shortages have become more serious with a decrease in runoff discharge upstream and an increase in water demand (Chaiwat, 1994, Roongrueng et al., 1996, Sanyu et al., 1999). The rice prices hover at a low level. Under such circumstances, now is a turning point in paddy farming. Modernized water management systems suitable for these changes are actually needed.

A Japanese Project Type Technical Cooperation named " The Modernization of Water Management System (MWMS) Project in Thailand " has been implemented since April 1999 to improve water management and to promote crop diversification (Shioda et al., 2002). This paper presents the progress and achievements of the activities in the water management field from April 1999 to March 2002.

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II Modernization of Water Management System Project

In 1996, the Government of the Kingdom of Thailand made a formal request of the Project Type Technical Cooperation to the Government of Japan to establish a modernized water management system. A Record of Discussion was signed in December 1998 and the project started on 1 April 1999 (Record of Discussions between Japanese Implementation Study Team and Authorities Concerned of the Government of the Kingdom of Thailand on Japanese Technical Cooperation for the Modernization of Water Management System Project, 16 December 1998).

The Royal Irrigation Department (RID) and the Department of Agricultural Extension (DOAE) have implemented the project under the technical and financial support of the Japan International Cooperation Agency (JICA) and the Department of Technical and Economical Cooperation (DTEC). The project period is for five years between April 1999 and March 2004. The Overall Goal, Target, Project Purpose, Activity and Expected Output were as follows:

<Overall Goal>:

To increase farmers' income through sustainable farming

<Target (Goal that should be attained within 3 to 5 years after the end of the project)>:

In the upper east bank (hereafter referred to as "UEB") of the Chao Phraya Delta, the planted acreage of dry-season's field crops that presupposes effective irrigation water utilization is expanded, and crop diversification is also promoted.

<Project Purpose>:

In dry-season's irrigation period, through effective irrigation water utilization, the planted acreage of dry-season's field crops in the Model Area (18R canal area) is expanded, and crop diversification is also promoted.

<Activity>:

1-1 Improvement of on-farm development methodology of On-farm level irrigation / drainage facilities

1-2 Improvement of development methodology of lateral level irrigation facilities

2-1 Improvement of irrigation and drainage planning, and facilities' operation

2-2 Improvement of data communication system

3-1 Strengthening of water users' groups

3-2 Improvement of water management method in on-farm level
4-1 Examination and extension of the dry-season's field crops and their suitable cultivation / irrigation technology
4-2 Establishment and strengthening of the farmers' groups for farming and the supporting system for them
5-1 Implementation of training for the local technical staff of RID and extension staff of DOAE
5-2 Dissemination of outputs of activities through seminars

<Expected Output in the water management field (2-1)>:

Decision Support System for the operation of main facilities in the UEB of the Chao Phraya Delta is developed, and as a result of it, related RID offices and farmers can compare the planed and actual data of water allocation.

<Objectively Verifiable Indicator for the output of (2-1)>:

By the end of September 2003, digitized O&M data in the UEB of the Chao Phraya Delta and related hydrology data are arranged and opened daily throughout the network.

The organization of the project as of March 2002 is as follows:

Project Director: Director General, RID
Deputy Project Director: Deputy Director General for O/M, RID
Project Manager: Director, Office of Hydrology and Water Management, RID
Five long-term Japanese experts:

1) Chief Advisor/System Development
2) Coordinator/Training
3) Water Management
4) Water Users' Organization
5) On-farm Facilities

There are five Working Groups, namely 1) Basin and Delta Level Water Management, 2) On-farm Facilities, 3) Water Users' Organization, 4) Farming, and 5) Training (Administration). The Basin and Delta Level Water Management Working Group consists of members from water management and system development fields. The project also has a Joint Coordinating Committee (JCC) to formulate the annual work plan and review overall progress.

The objective area of the project is basically the whole Chao Phraya River basin. The model area is set up at the command area of the 18R lateral irrigation canal system. The 18R canal is one of the lateral irrigation canals in the Chainat-Pasak main canal governed by the Khok Krathiam O/M Project Office. The most of activities related to on-farm level water management have been carried out at this model area.

The catch phrase of the project is "Common Ownership of Water Management Process through the introduction of PIM (Participatory Irrigation Management) and improvement of the information communication system". Corresponding to the activities in the project, more appropriate water management can to be established by 1) Efficient data collection, summarization and judgements, 2) Rehabilitation and new construction of facilities, 3) Formation and strengthening of water user groups, and 4) Introduction of field crops in the dry season.

Ⅲ Activity in the Water Management Field

The water management field is in charge of Activity 2-1 " Improvement of irrigation and drainage planning, and facilities' operation". The PO (Plan of Operation) for the whole period and the third year (Japanese fiscal year of 2001) are shown in Table 1 and Table 2, respectively. The members of the water management field (hereafter referred to as "Members") are twelve Thai counterparts and

Table 1 PO for the whole period

Activities	Targets/(Indicators)	Schedule (Japanese Fiscal Year)																				Inputs
		1999				2000				2001				2002				2003				
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	
2. Improvement of basin and delta level water management																						
2-1. Improvement of irrigation and drainage planning, and facilities' operation	Decision Support System for the operation of main facilities in the upper east bank of the Chao Phraya Delta is developed, and as a result of it, related RID offices and farmers can compare the planed and actual data of water allocation. (By the end of September 2003, digitized O/M data in the upper east bank of the Chao Phraya Delta and related hydrology data are arranged and opened daily throughout the network.)																					Dispatch of Japanese long-term expert, Dispatch of Japanese short-term expert, Necessary technical equipment, Counterpart training in Japan, Land, Building and facilties, Assignment of C/Ps and other staff, Project cost (Remarks) R8:Regional Irrigation Office 8 KK:Khok Krathiam O/M Project PP:Phra Pimol O/M Project
2-1-1. Analysis of current situation, and examination for efficient water manegement																						
2-1-1-A. Clarification of existing problems																						
2-1-1-B. Preliminary proposal of new water management system																						
2-1-2.Examination of appropriate water resources utilization																						
2-1-2-A. Review and analysis of related planning																						
2-1-2-B. Learning from the experience in the world																						
2-1-2-C. Development of decision support system for practical water operation																						
2-1-2-D. Application of proposed water management method in the upper east bank of the Chao Phraya Delta																						

Note : 1st quarter is April to June, 2nd quarter is July to September, 3rd quarter is October to December and 4th quarter is January to March. (as of 5 September 2001)

Name of responsible persons is omitted from the Table.

Table 2 PO for the third year (Japanese fiscal year 2001)

Activities	Targets/(Indicators)	Schedule (Japanese Fiscal Year 2001) 4	5	6	7	8	9	10	11	12	1	2	3	Inputs
2. Improvement of basin and delta level water management														
2-1. Improvement of irrigation and drainage planning, and facilities' operation	Decision Support System for the operation of main facilities in the upper east bank of the Chao Phraya Delta is developed, and as a result of it, related RID offices and farmers can compare the planed and actual data of water allocation. (By the end of September 2003, digitized O/M data in the upper east bank of the Chao Phraya Deita and related hydrology data are arranged and opened daily throughout the network.)													Dispatch of Japanese short-term expert, Dispatch of Japanese long-term expert, Necessary technicai equipment, Counterpart training in Japan, Land, Building and facilities, Assignment of C/Ps and other staff, Project cost (Remarks) R8:Regional Irrigation Office 8 KK:Khok Krathiam O/M Project PP:Phra Pimol O/M Project
2-1-1. Analysis of current situation, and examination for efficient water management														
2-1-1-A. Clarification of existing problems														
a. Confirmation of current situation														
b. Confirmation of concept and practical water management														
c. Finding of limiting factors														
2-1-1-B. Preliminary proposal of new water management system														
a. Proposal of data communication system														
b. Proposal of decision support system														
2-1-2. Examination of appropriate water resources utilization														
2-1-2-A. Review and analysis of related planning														
a. Future demand of irrigation water														
b. Development of new water resources														
c. Change of dam operation rule														
d. Strategy of saving water														
e. Effective use of flooding water														
2-1-2-B. Learning from the experience in the world														
2-1-2-C. Development of decision support system for practical water operation														
a. Improvement of database														
b. Information networking														
c. Arrangement of water management information by GIS														
2-1-2-D. Application of proposed water management method in the upper east bank of the Chao Phraya Delta														
a. Trial and making guideline														
b. Effective use of water management software														
c. Arrangement of regulator operation gudeline for the Chainat-Pasak canal														
d. Transferring developed technologies to the projects and persons concerned														

(as of 5 September 2001)

Japanese water management expert as of March 2002. They belong to the Basin and Delta Level Water Management Working Group.

The water management field aims for more appropriate water management in the Chao Phraya River basin. However, 1) to obtain substantial achievements, 2) to have close communication with on-farm level activities, and 3) considering the limitations of time and human resources, the main focus is put on contributions to practical water operations in the UEB of the Chao Phraya Delta. Priorities are given to the following activities:

1) Confirmation of existing irrigation and drainage systems.
2) Common understanding of water allocation planning and actual situation in the dry season.
3) Preparation of strategies/ideas to improve water management.
4) Development of decision support system for practical water operation.
5) Test of electromagnetic type rainfall gauge, Walky-Talky (mobile radio) and GPS (Global Positioning System).

Thai counterparts come from various branches of the Office of Hydrology and Water Management, RID. The project has contributed to the accumulation of information and experience. All information obtained by the MWMS project is basically open to all members. This point is very important, because the basic idea of the Japanese Project Type Technical Cooperation is to develop the human resources. Some training such as O/M data entry methods, regulator operation guidelines based on flow analysis, and water allocation planning were given to the staff of the O/M Project Offices.

Many kinds of technical equipment were provided by JICA to promote these activities. Three short-term experts supported the activities.

Ⅳ Outline of the Upper East Bank of the Chao Phraya Delta

The Chao Phraya River basin has a catchment area of 162,000 km^2 including 1.34 million ha of low-lying delta area. The main water resources of the basin are stored in the Bhumibol reservoir dam with a storage capacity of 13,500 MCM (million cubic meter) and the Sirikit reservoir dam with a storage capacity of 9,500 MCM. The Pasak reservoir dam with a storage capacity of 780 MCM began operation in November 1999. The Chao Phraya diversion dam in the Chao Phraya River at Chainat enables the allocation of water for the delta area. The location of the main water operation facilities is shown in Fig. 1. The area marked by diagonal line shows the UEB of the Chao Phraya Delta.

Total area of the UEB of the Chao Phraya Delta is 244,000 ha including 218,000 ha of irrigated area. This area is located in a part of Chai Nat, Nakhon Sawan, Lop Buri, Saraburi, Sing Buri, Ang Thon and Phra Nakhon Si Ayutthaya provinces. Water resources for this area are from rainfall and the Chao Phraya River. Fig. 2 shows the main water operation facilities in the UEB of the delta and surrounding area. The Chainat-Pasak and Chainat-Ayutthaya canals are used to convey water from the Chao Phyara River throughout the Manorom regulator and the Maharaj regulator, respectively. The maximum flow capacity of the Chainat Pasak canal is 210 m^3/s and that of the Chinat-Ayutthaya canal is 75 m^3/s. Those canals were constructed under the Greater Chao Phraya Project along with lateral distribution canal and drainage systems.

The land elevation in the irrigated area varies from 1 m to 19 m above the mean sea level (MSL). Annual rainfall in the area varies between 1,000 mm to 1,600 mm. Fig. 3 shows the average monthly rainfall in Lopburi. The rainy season starts from middle of April and ends late in October. At the beginning of the rainy season, it rains locally and for a short period. Non-rain days sometimes continue for quite a long period. The runoff ratio is roughly between 15 and 30% (Atthaporn, 1999). A tidal effect is sometimes present in Ang Thong. The UEB area often suffers from water shortage and flooding. Therefore, water operations are essential for the prosperity of the area.

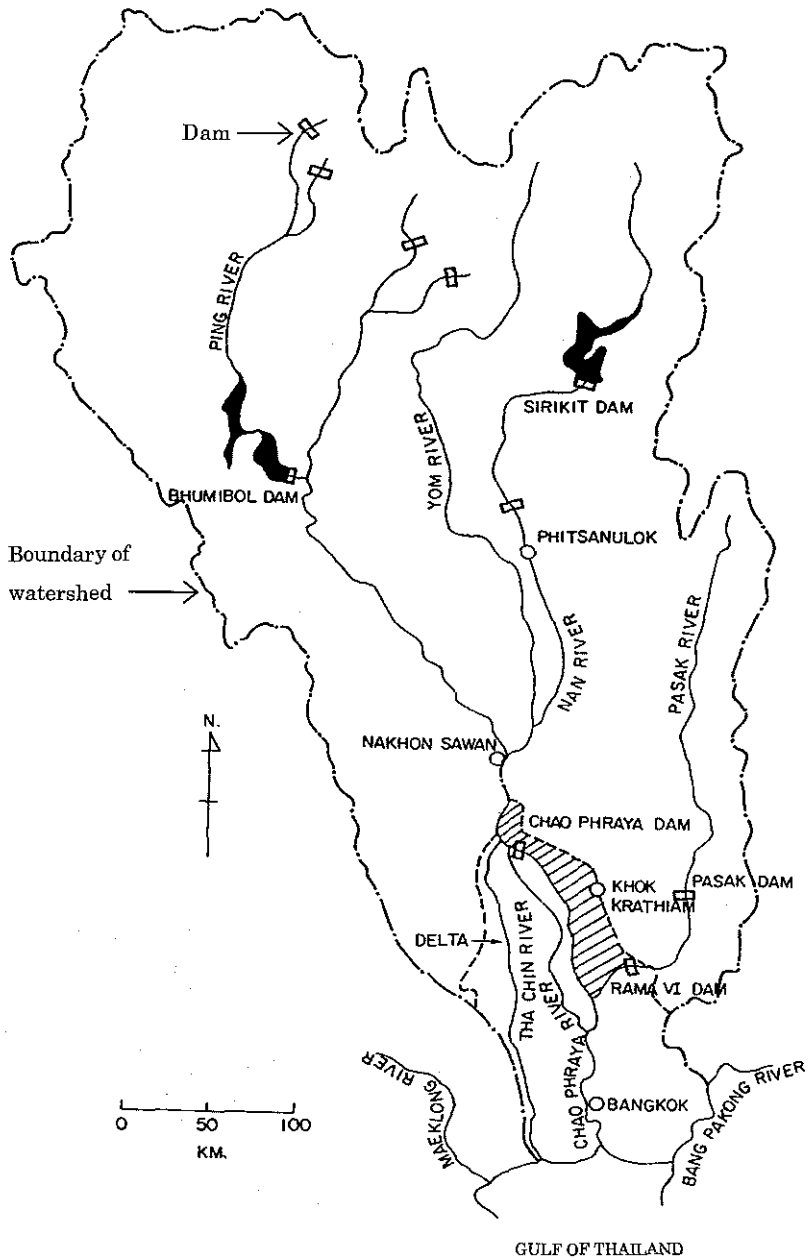


Fig. 1 Outline of the Chao Phraya River basin

V Progress and Achievements

In the first and second year of the MWMS project, the Members tried to confirm existing condition of water management and to arrange countermeasures for improvement (Piphat et al., 2000, Yuyama et al., 2000a). They also tested electromagnetic type rainfall gauges, mobile radio and GPS to collect data more efficiently. The development of a decision support system for practical water operation substantially began from the third year. In this chapter, some progress and achievements are highlighted.

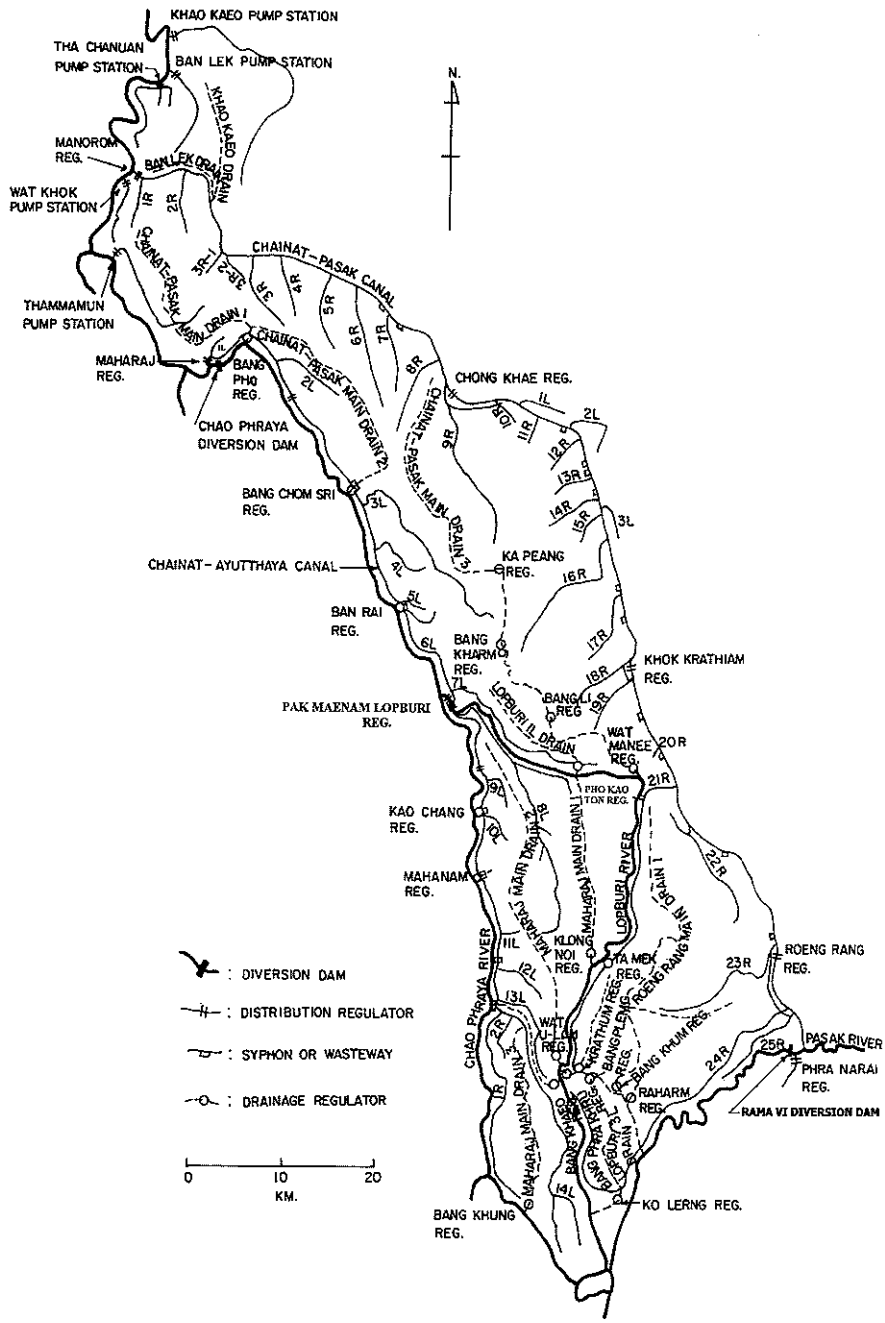


Fig. 2 Location of water operation facility in the UEB of the Chao Phraya Delta

1 Existing water management conditions and proposals for improvement

a Irrigation and drainage systems

Before the MWMS project, necessary information for water management was not arranged systematically and some data needed to be updated. Through field surveys and hearings, the existing conditions of the irrigation and drainage systems became clear. Fig.2 shows a part of results. They were reflected in the GIS (Geographical Information System) layers and will be introduced later.

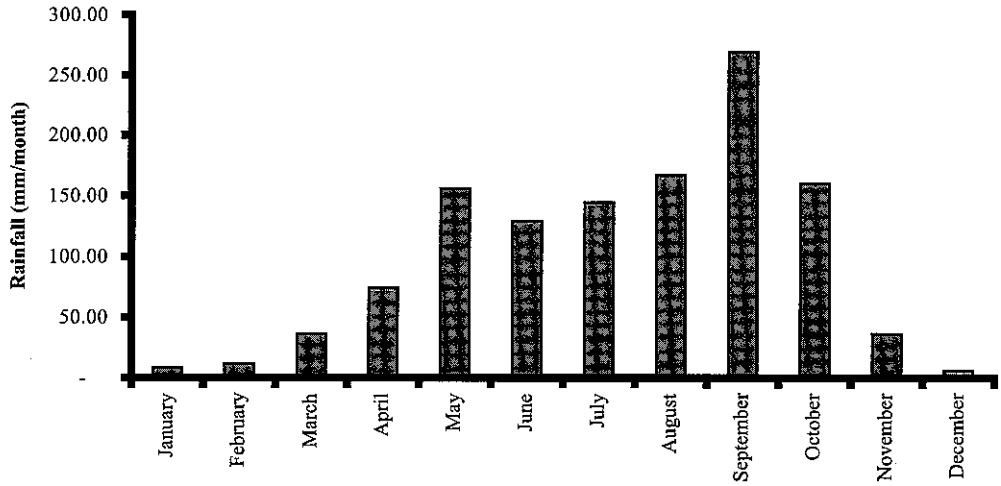


Fig. 3 Average monthly rainfall in Lopburi from 1952 to 2000

b Organization of water management

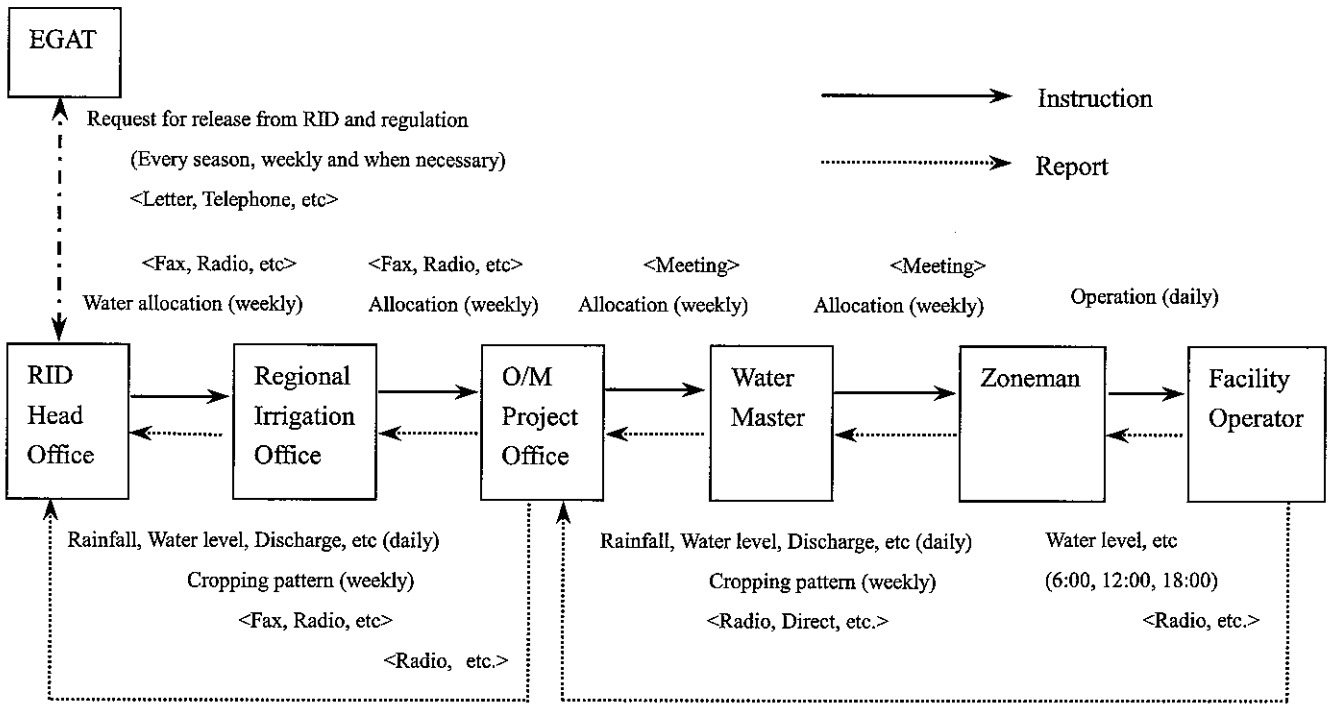
The RID is the main organization to carry out water management. The east bank of the Chao Phraya Delta is under the control of Regional Irrigation Office No.8 (RIO-8). There are five O/M Project Offices in the UEB of the delta, namely Manorom, Chong Khae, Khok Krathiam, Roeng Rang and Maharaj. They are responsible for planning water allocation, daily water operations, monitoring, flood protection and so on.

Fig. 4 shows the organization and flow chart of information in water management. Within RID, contents of information in instructing direction are water allocation and facility operation at the main water operation facilities. Contents of information in reporting direction are daily rainfall, water level, discharge, condition of facility operation and weekly cultivation condition under the control of O/M Project Offices. Table 3 shows an example of data sheet from Khok Krathiam O/M Project. Information had been recorded by hand before 2000. Facility operation at the tertiary canal level is not contained in the report.

In terms of field data, Zonemen and Facility Operators who belong to the O/M Project Office collect most of the data. Data are reported to the O/M Project Office by way of the Water Master or directly. Facility Operators consist of gate operator, generally called Gate Tender, pump operator and canal operator, generally called Canal Keeper. For example, there are two Water Master Offices and sixteen Zonenman Offices in the Khok Krathiam O/M Project.

In the delta area, some O/M Project Offices send their reports to both the RID Head Office (HO) and their RIO, whereas, others send them only to their RIO according to the data communication conditions. Water Allocation & Operation Center at RID HO is in charge of collecting and recording information. Communication media used for information exchange are mainly oral communication, voice radio communication, telephone, and facsimile. In the UEB of the delta, each O/M Project Office sends daily report to RIO-8, then RIO-8 sends them to RID HO. They usually use facsimile. According to 22 surprise inspections from 15 December 1999 to 12 February 2002, 76% of the information arrived at RID HO before 9:30 am on the same day and 94% arrived by the next day.

Recently, the RID shifted the authority of daily water operation from HO to RIO. Under normal water conditions, RID HO orders only water operation at the Chao Phraya diversion dam and total water allocation for each RIO command area. RIO-8 determines water operation at the main regulators such as Manorom, Chong Khae, Khok Krathiam, Roeng Rang and Maharaj. RIO-8 also pays attention



(Reporting media is different depending on the mode of communication)

Fig. 4 Flow chart of information in water management

to main drainage regulators. Lateral and tertiary canal levels are under the responsibility of each O/M Project.

c Water allocation planning for the dry season

Water allocation in the dry season is a very important subject to prevent water conflicts (RID, 1998a and 1998b). Many regulations are made among the organizations concerned including RID. The discussion starts from October of the previous year to determine water allocations between January and June (hereafter referred to as "WM dry season"). The symbol "WM" represents Water Management. The period of the actual rainy season is usually from the middle of April. The periods of the WM dry season (January-June) and the WM wet season (July-December) are based on RID's methodology for water management. The RID, Electricity Generating Authority of Thailand (EGAT) and other related organizations collect information and estimate the remaining water storage volume as of the 1st of January in the main dams and reservoirs. After determining the water resources available for six months, water allocation planning is discussed. The Water Allocation Branch at RID HO estimates total water requirements based on collected information and makes a water operation plan. Then, the RID proposes the plan of weekly release discharge from upstream reservoir dams to the EGAT. The primary purpose of dam operation by EGAT is hydroelectric power generation. However, water released from the dams is used effectively in most cases. If the water levels at the dams become higher than the designed upper rule curve, the EGAT has to release excess water to protect the dams and mitigate flooding. The plan of weekly release discharge is sometimes revised after the beginning of the WM dry season.

It is generally understood that about 6,600 MCM is needed in the WM dry season for irrigation, domestic and industrial consumption, navigation, and salinity control (Chaiwat, 1995). The water supply for Bangkok is about 700 MCM. Domestic and industrial consumption, salinity control, and navigation for the delta area are 700 MCM, 600 MCM and 300 MCM, respectively. The priority of the water allocation is different year by year. Irrigation becomes the last priority in case of serious water shortage. The allocated water resources for irrigation determine cultivation planning in the WM dry season. General criteria are as follows:

Table 3 Daily O/M data sheet (Khok Krathiam O/M Project)

Facility Information	Max. Water level of previous day		Average discharge of previous day (3)	Upstream water level at regulator or pump (4)	Downstream water level at regulator or pump (5)
	Upstream (1)	Downstream (2)			
	(m. mean sea level)		(m^3/s)	(m. mean sea level)	
Distribution canal					
1. Khok Krathiam Reg.	11.22	10.14	101.73	11.18	10.20
2. Intake 18R	11.22	10.14	2.95	11.18	11.12
3. Intake 19R	10.09	-	-	10.16	-
4. Intake 20R	9.89	-	-	10.01	-
5. Intake 21R	9.72	9.22	7.08	9.79	9.29
6. Intake 22R	9.53	9.42	4.45	9.61	9.52
Drainage canal					
1. Bang Li Regulator				-	-
2. Wat Manee Reg.				4.93	4.78
3. Lopburi Siphon				4.70	-
4. Pho Kao Ton Reg.				-	-
5. Klong Ta Mek Reg.				3.68	3.67
6. Klong Noi Reg.				4.08	4.08
7. Krathum Reg.				2.58	1.97
8. Siphon km. 92+626*				-	-
9. Waste Way km. 95+615*				9.97	-
10. Siphon km. 108+792*				-	-
11. Siphon km. 115+066*				-	-

Facility Information	No. of gate or operating pump (6)	Duration of gate opening or pump operation (7)	Length of gate opening x number (8)	Discharge (9)	Rainfall (Station code) (10)
	(-)	(hour)	(m)	(m^3/s)	(mm)
Distribution canal					
1. Khok Krathiam Reg.	4	24	S 1.10 x 4	96.62	(CPK 27) 50.9
2. Intake 18R	1	24	S 2.00 x 1	2.95	(CPK 16) 48.6
3. Intake 19R	1	24	with 18R	-	(CPK 17) 42.0
4. Intake 20R	1	24	C	0.0	(LOP 1) 32.7
5. Intake 21R	2	24	S 0.80 x 2	7.08	(LOP 2) 27.8
6. Intake 22R	2	24	1.50 x 2	4.22	(LOP 3) 21.0 (LOP 5) 13.6 (LOP 6) 3.2 (LOP 7) 10.4 (CPK 18) - (CPK 33) 10.5
Drainage canal					
1. Bang Li Regulator	3	-	-	-	
2. Wat Manee Reg.	3	24	F x 3	-	
3. Lopburi Siphon	?	-	-	-	F: Free flow
4. Pho Kao Ton Reg.	5	-	-	-	S: Submerged flow
5. Klong Ta Mek Reg.	3	24	F x 3	-	
6. Klong Noi Reg.	1	24	F x 1	-	C: Closed
7. Krathum Reg.	1	0	C	0.0	
8. Siphon km. 92+626*	1	0	C	0.0	*Refer to km from the origin of Chainat-Pasak canal
9. Waste Way km. 95+615*	3	0	C	0.0	
10. Siphon km. 108+792*	1	0	C	0.0	
11. Siphon km. 115+066*	?	-	-	-	

Remark : Values in (4), (5), (6), (8), (9) are observed at 6:00 a.m.. "-" indicates missing data.

1) When the remaining active storage volume at dams as of 1st January is more than 8,000 MCM, a target cultivation area 480,000 ha is recommended.
2) When the remaining active storage volume at dams as of 1st January is between 5,000 MCM and 8,000 MCM, target cultivation area between 320,000 ha and 480,000 ha is recommended.
3) When the remaining active storage volume at dams as of 1st January is less than 5,000 MCM, cultivation planning is canceled.

However, these criteria can be modified by political decisions. For example, although the remaining water storage in the upstream dams was not enough in 1999, the RID accepted a plan to cultivate 300,000 ha in order to mitigate the economic crisis. For the WM dry season of 2000, new methodology to determine the total release discharge from upstream dams was adopted. The inflow and demand of water for the following three years were estimated, then the most stable water supply plan was chosen. The following priorities were adopted to determine the location of cultivation areas in the WM dry season of 1998:

1) First priority: to allocate water to paddy fields where wet season cultivation in 1997 was impossible.
2) Second priority: to allocate water to farmers who had damage from violent natural calamities in 1997.
3) Third priority: to allocate water to farmers who are scheduled on receiving irrigation water in the WM dry season of 1998 based on a rotational rule.
4) The last priority: to allocate water to farmers who want to cultivate in order to increase their income.

The following is official procedures within RID to determine the location of cultivation:

1) First, RID HO informs RIO the amount of available water resources between January and June and the plans of the total amount of water allocated to each RIO.
2) RIO selects the command area where irrigation water is supplied based on rotation rule. The area is selected by lateral canal basis.
3) RIO informs the results to O/M Project offices.
4) O/M Project Offices discuss with farmers and determine a plan of cultivation areas and daily water distribution.
5) O/M Project Offices make a daily water allocation plan and report to RIO.
6) RIO arranges the collected information from the O/M Project offices and reports to RID HO.

The RID monitors water conditions and makes a report. Table 4 shows the comparison between the plans and the results in recent years. There are water resources from the Maeklong River basin and the Pasak reservoir dam. In 2000, 1,000 MCM of water transfer from the Maeklong river basin to the Tha Chin River was planned, however only 420 MCM were actually transferred. In terms of the Pasak reservoir dam, 534 MCM was planned to be released, but actually 753 MCM were released. Table 5 shows the planning of water allocation for the UEB of the delta in the WM dry season of 2000.

d Practical water operation

The RID and the EGAT try to maintain the planned release discharge from the upstream reservoir dams and intake discharge from main intake regulators. However, they have to be modified according to the influences of rainfall and unexpected water demand. Fig. 5 shows the comparison between planning and results of intake discharge from the Manorom regulator in 2000. The planning of intake was 1,046 MCM. In 2000, the rain started earlier than normal. The water level at the Sirikit reservoir dam became near to the upper rule curve from the middle of May. EGAT released more water than the plan because of a high demand for electricity. This caused an increase in discharge at the Chainat-Pasak canal. As a result, the practical intake became 1,666 MCM. In terms of the total RIO-8 area, although the planned water use was 1,735 MCM, they actually received 2,387 MCM. The plan of the cultivated area in RIO-8 command area was 115,000 ha. The practical cultivation area became 197,000 ha, almost the maximum potential in the WM dry season.

Table 4 Water allocation plan from the Bhumibol and Sirikit dams

		1993	1994	1995	1996	1997	1998	1999
Active Storage on 1st January		5,357	2,048	12,733	14,582	12,107	8,239	3,879
1. Consumption for domestic & Industrial use		550	700	1,100	1,800	1,650	1,600	550
-North of Nakhon Sawan		250	300	500	900	800	800	150
-Greater Chao Phraya Project		300	400	600	900	850	800	400
2. Dry season cultivation		2,100	500	3,300	4,950	4,200	3,400	2,050
3. Navigation		300	0	300	400	300	300	0
4. MWA (Tap water)		650	550	700	750	750	750	650
5. Salinity Control		400	250	600	600	500	450	350
Sum of 1-5	Plan	4,000	2,000	6,000	8,500	7,400	6,500	3,600
	Actual	4,610	1,894	7,216	9,643	8,556	6,656	2,575
6. Paddy field area (million rai)	Plan	1.50	0	2.80	3.50	3.30	2.70	1.90
	Actual	1.96	1.77	3.19	4.15	4.06	3.79	3.49

1) Water allocation plan in the WM dry season between January and June was arranged.

2) Side flow is not taken into account.

3) MWA: Metropolitan Waterworks Authority

4) Paddy field area is sum of irrigated area. (1.0 rai = 0.16 ha)

		2000	2001	2002
Active Storage on 1st January		11,930	13,585	14,250
1. Water use above Nakhon Sawan		1,300	1,300	1,300
-Phitsanulok Project		500	500	500
-Other		800	800	800
2. Water use in the Greater Chao Phraya Project		3,300	4,300	4,300
3. Navigation		300	300	300
4. MWA (Tap water)		750	750	750
5. Salinity Control		350	350	350
Sum of 1-5	Plan	6,000	7,000	7,000
	Actual	6,513	6,879	
6. Release from the Pasak dam	Plan	500	500	500
	Actual	762	600	
7. Paddy field area (million rai)	Plan	3.10	3.35	3.50
	Actual	4.90	4.39	

1) RID changed the format from the planning of 2000.

2) The value of active storage in 2002 is predicted.

Table 5 Water allocation plan for the UEB of the Chao Phraya Delta during the WM dry season of 2000 (MCM)

	Manorom	Chong Khae	Khok Krathiam	Roeng Rang	Maharaj
Rice	80	115	100	30	147
Vegetable	0	14	8	12	15
Fruit	2	7	4	1	0
Fish pond	1	2	1	2	0
Domestic use	12	1	17	5	0
Sum	95	145	130	50	162

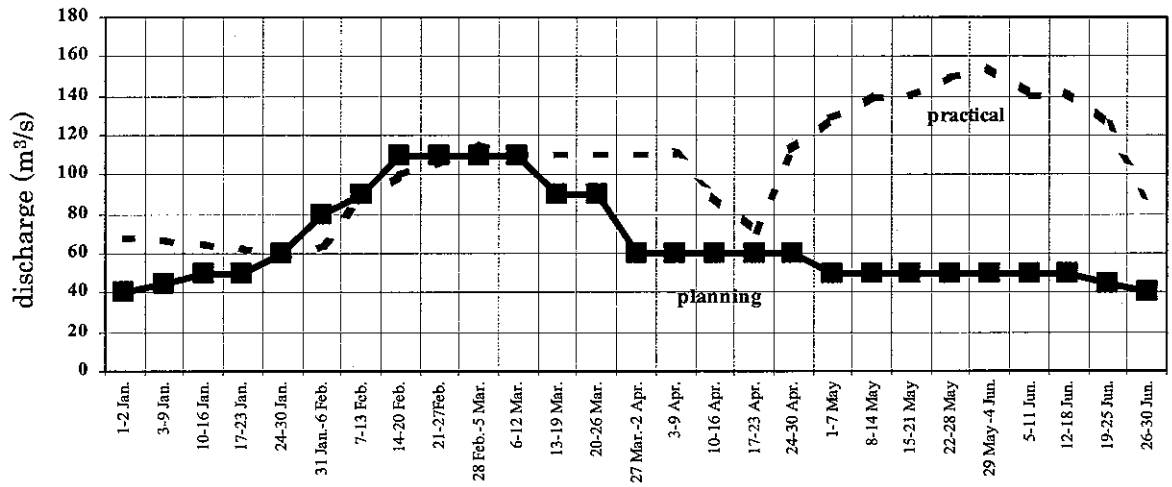


Fig. 5 Planning and practical intake discharge from the Manorom regulator

Main indicator of practical water operation by RIO-8 is as follows:

<WM dry season (January-June)>

1) To maintain the upstream water level of the Chao Phraya diversion dam higher than 15.8m (MSL).
2) To maintain the target upstream water level of regulators in the main canals.
3) To follow the water allocation plans basically and control the regulators weekly.
4) To maintain the total amount of allocated water for the WM dry season strictly.
5) To maintain the upstream water level of the Rama VI diversion dam higher than 6.7 m (MSL).
6) To consider the water conditions obtained from O/M Project offices.
7) To regulate the fluctuations of water levels at the Chao Phraya diversion dam by the operation of upstream reservoir dams.
8) To intake water directly from the Chao Phraya River at the Chulalongkorn pump station by Ransit Tai O/M Project for irrigation and dilution of polluted water.
9) To keep the water level in the area along the coastal area according to the monthly target retention water level such as higher than 0.0 m (MSL).

<WM wet season (July-December)>

1) To maintain the upstream water level of the Rama VI diversion dam lower than 7.5 m (MSL).
2) To monitor runoff from the left bank of the Chainat-Pasak canal. For this, the staff of Chong Khae O/M Project collects the rainfall information at Wang Pleong and Khok Samran everyday. When the daily rainfall is larger than 100 mm, the intake discharge from the Manorom regulator will be decreased and the target upstream water levels at Chong Khae regulator and Khok Krathiam regulator will be lowered.
3) To maintain water levels at the Chulalongkorn pump station lower than 1.2 m (MSL).
4) To maintain the water levels along the coastal area lower than 0.3 m (MSL). If levels become higher than 0.3 m, pumps will be operated.
5) To hear/monitor the inflow discharge from RIO-9 area to RIO-8 area for flood control.

e Recent changes in the background of water management

In the delta area, rice cultivation more than five times per two years is possible now where water conditions are good. Historically, rice cultivation during the dry season started only about 30 years ago. In those days, farmers obtained irrigation water every two years by rotation. It was a new trial. Before that, only one crop a year was possible. The impact of this transition seemed large (Takaya, 1973 and 1982, Kaida, 1973). The rice cultivation area increased rapidly, but soon came to be limited by the available water resources and existing capacity of irrigation facilities (Virat, 1992, Water Operation

Branch, 1999). The flow capacity of the irrigation system under the Great Chao Phraya Project is equivalent to about 7 mm/d for supplementary irrigation supply. This supply can meet about 60 % of the water requirements for paddy farming. After unsuccessful regulation of cultivated areas with farmers, some farmers started rice cultivation on their own will. Farmers were able to cultivate rice any time if the water was available, because non-photosensitive varieties had been developed. Above changes collapsed the order of water operation at on-farm level in some areas.

Some O/M Project areas, especially the Project areas in the west bank of the delta, shifted the main rice cultivation from the rainy season to the dry season after the Greater Chao Phraya Project to escape flood disasters. Fig. 6 shows the average crop intensity of paddies in the dry season between 1991 and 1996. The average was 30-40 % (Sanyu et al., 1999). There were large differences between locations. The ratio of the UEB was relatively low. Understanding crop intensity throughout the year and histrical background are essential for considering equality or fairness among O/M projects. However, to make persuasive water allocation rules considering both priorities and preferences is not easy.

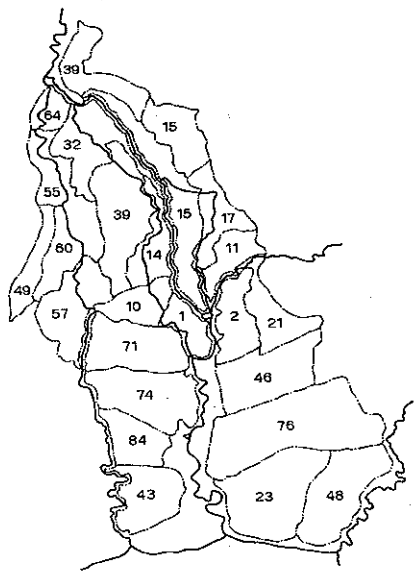


Fig. 6 Crop intensity of paddies during the dry season by the O/M Project (%)

Recent changes in the background of water management in the delta area can be summarized as follows:

1) The amount of rainfall upstream of the Chao Phraya River basin tends to decrease (Chaiwat, 1994). It causes a decrease of inflow discharge into the upstream dams (Bhumibol and Sirikit reservoir dams).
2) The intake discharge upstream of the delta area increased greatly, because the Department of Energy Development and Promotion (DEDP) installed many pumps. This decreased the discharge at the Chao Phraya diversion dam where most irrigation water is delivered through the main regulators. Fig. 7 shows the changes in discharges at Nakhon Sawan and Chainat in the Chao Phraya River. (The hydrology station at Nakhon Sawan is about 94 km upstream or 50 km north of the Chao Phraya diversion dam, and Chainat is just downstream of the diversion dam.)
3) In addition to supplementary irrigation during the rainy season, water allocations for domestic and industrial use, and flood control have been requested.
4) Rice cropping calendar has changed even within the command area of some thousand ha. Farmers do

not grow rice simultaneously even within the lateral irrigation canal area.

5) The dry season rice cropping calendar has shifted ahead in the west bank of the delta. It sometimes starts in November.
6) Situation of over cropping continues as shown in Table 4.
7) Many gates or regulators have been constructed at the end of lateral canals, main drainage canals even in the gravity irrigation system areas as well as in the Lopburi River. Those facilities increase the ability to store water in the area.
8) Farmers tend to have their own pumps and ponds.
9) Because floating rice areas and deep-water rice areas have decreased, it has become difficult to convey excess flooding water into such paddy fields.
10) The Pasak reservoir dam contributes to mitigation of water shortage and flood control especially in the lower east bank of the delta.

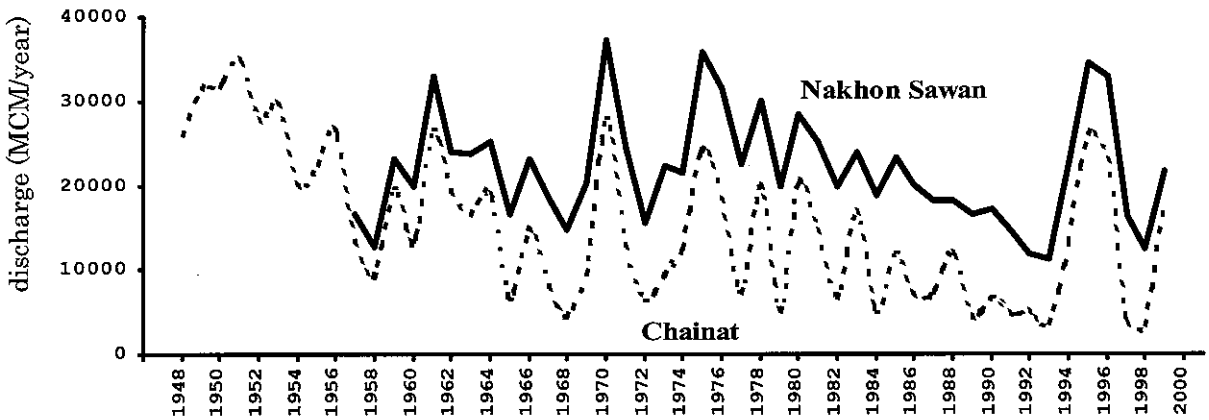


Fig. 7 Changes in annual discharge at Nakhon Sawan and Chainat in the Chao Phraya River

f Difficulties and problems of water management

Much research and many international cooperation projects have been implemented, and many proposals were given for water management. These contributions are great, but RID still has the following difficulties with practical water management in the delta area:

1) Water traveling time from the upstream dams to the fields requires much time as long as 1-3 weeks.
2) Arrival discharge at the Chao Phraya diversion dam changes with fluctuations in release discharge from the upstream dams, because EGAT decreases the release on holidays. Fig. 8 shows a comparison between total release discharge from the upstream dams and discharge at Nakhon Sawan in the Chao Phraya River.
3) It is difficult to accurately estimate runoff discharge (side flow) from rainfall information.
4) Much water is consumed upstream of the delta area beyond the control of RID. Sometimes, only half of the water released from the upstream dams arrives at the Chao Phraya diversion dam. The regulation of water allocation to pump users upstream during the planning stage is still not enough. This phenomenon can be estimated during the WM dry season as shown in Fig. 8.
5) There is no regulating reservoir/pond that enables released water from the upstream dams to be used more effectively during the occurrence of unexpected rainfall.
6) Water levels in the main irrigation canals sometimes have to be maintained high in order to supply water to some lateral canals where intake sill elevations are relatively high as compared to the standard minimum water level as shown in Fig. 9.
7) It is difficult to use local rainfall more effectively under the present monitoring system and with the

number of staff members available.

8) Cooperation of farmers in maintenance of on-farm facilities and keeping the cultivation plan during the WM dry season is not sufficient. On-farm facilities at lateral and tertiary canals are sometimes broken.
9) When farmers start planting after a light rain at the beginning of the rainy season and the rain does not continue, the young rice plants wither and die if irrigation water is not supplied. This weather condition is called a dry spell. Farmers strongly request irrigation water even though their paddy fields are not in the irrigation schedule.
10) A third party person sometimes applies pressure to RID for water allocation.

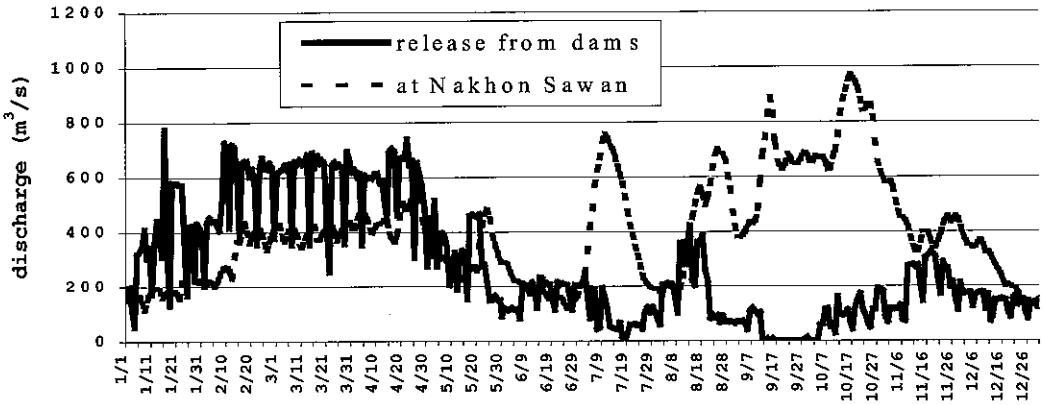


Fig. 8 Comparison between release discharge from the upstream dams and discharge at Nakhon Sawan in 1998

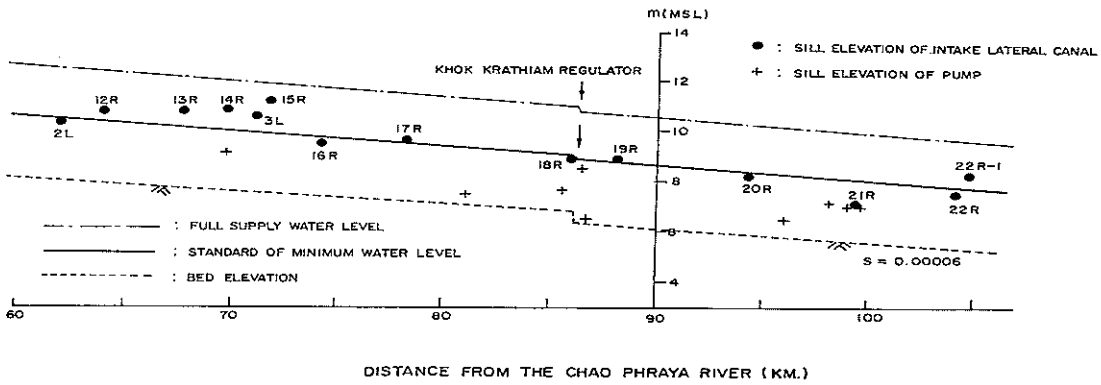


Fig. 9 Sill elevation of water operation facilities and water level profiles along the Chainat-Pasak canal

g Multi-functionality of floating rice farming

Paddy farming in Asia monsoon areas is strongly connected to the rural social system. Good management of paddy fields is essential for not only food production but also natural resources conservation. Paddy farming including related water management plays the following important roles and function (Yuyama et al., 1996, Yuyama, 2000b, Taniyama, 2001):

1) Flood mitigation as retarding basin
2) Water resources for downstream area as regulating pond
3) Water quality and ecosystem conservation
4) Protection from soil erosion
5) Production of oxygen
6) Provision of recreational opportunities

One characteristics the Chao Phraya Delta is floating rice farming. Floating rice farming can be summarized as low input and low yield but sustainable farming. Cultivated floating rice areas have decreased from 228,000 ha in 1987 to 114,000 ha in 1997 (CTI et al., 1999). The storage volume of the floating rice area in 1997 was estimated to be 2,200 MCM by assuming the water depth was 2.0 m. The volume would be almost the same as the storage in the remaining paddy fields in the WM wet season if the water depth was assumed to be 0.2 m. For reference, the inundated volume of the flood of 1995 was estimated to be 15,900 MCM (CTI et al., 1999). It is impossible to protect metropolitan Bangkok from flooding without paddy fields. The distribution of the floating rice area is shown in Fig. 10. Floating rice area in the UEB of the delta in 1998 was 52,400 ha. Units of floating rice area are from some thousand to ten thousand ha. Each unit has a drainage regulator to control the water level. The role of artificial control of water has increased even in floating rice areas. Recently, newly constructed roads function as embankments.

Floating rice can grow flexibly corresponding to irregular increases in water level. It grows like rice grown in a dry field with weeds in the beginning stage. Then, the stem increases from 2 m to 5 m depending on water conditions. It takes 7-9 months from planting to harvest. The harvest starts from December or January after the water is drained. Floating rice field is also a living place for fish. Fish are caught to eat.

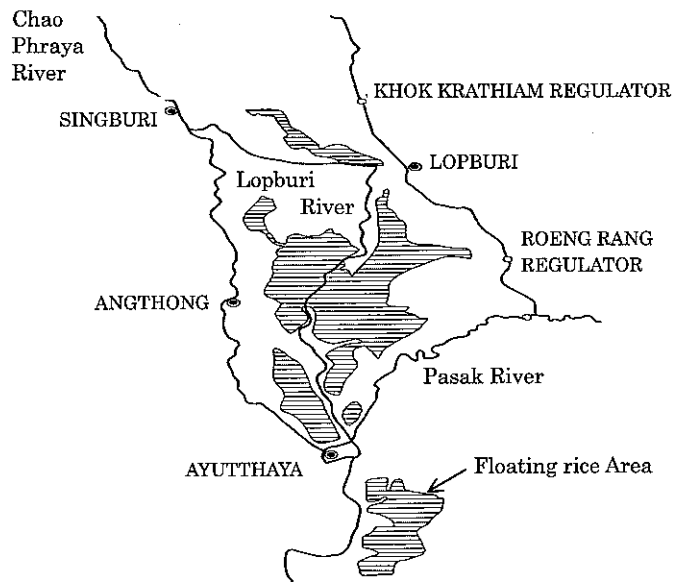


Fig. 10 Distribution of floating rice area in the east bank of the Chao Phraya Delta (1998)

Water released from the floating rice areas can also contribute to decrease salinity concentration at the downstream area during the beginning of the WM dry season. EC (Electric conductivity) in the irrigation and drainage canals of the UEB of the delta ranged between 15 and 30 mS/m. These values are equivalent to TDS (Total dissolved solids) of 100-200 mg/L. Compared to the EC standard for irrigation of 70 mS/m (Benchanee, 2000), measured values are low. Moreover, the released water functions to increase the water level and discharge in the Chao Phraya River. It is important for navigation, salinity control and tap water supply. In other words, it can decrease the release from the Chao Phraya diversion dam.

h Countermeasures to improve water management

Recently, much regulation and time is needed to construct large-scale dams or inter-basin water conveyance canals. On the other hand, water resources need to be developed to correspond increasing demands. More efforts have to be made by the O/M side. Saving irrigation water in the rainy season

and storing it in the upstream dams is essential to achieve a stable water supply in the WM dry season. Promoting crop diversification in the WM dry season will also contribute to improvement of a stable water supply. More close communication between the supply side and demand side is also needed.

Countermeasures to improve water management mainly in the basin and delta level can be considered as follows:

1) To develop and use a decision support system for water operations including feedback from experiences, databases, and analyses.
2) To promote the networking of information (Kobayashi et al., 1994) on water management, so as to find common benefits for RID offices and water users.
3) To strengthen communication between O/M Project Office, RIO, Hydrology Center and RID HO on input of collected data into computers and data usage.
4) To improve the rules and regulations of water allocation including preparation of benefit for contributions to saving of irrigation water.
5) To strengthen integrated watershed management by NWRC (National Water Resources Committee).
6) To promote participatory irrigation management (PIM) by farmers groups.
7) To strengthen a campaign for saving water.
8) To examine crop calendars by location from the view of increasing opportunities for reuse of water.
9) To examine the upstream dam operation rule curves with EGAT after reviewing proposed ideas (Sanyu et al., 1999, CTI et al., 1999, Horikawa et al., 1994, Horikawa, 1997).
10) To estimate side-flow into the upstream of the Chao Phraya River above Nakhon Sawan. The results can be used to control the release discharge from the upstream dams.
11) To reduce the amount of water released from the Chao Phraya diversion dam for salinity control and navigation in the WM dry season based on integrated studies.
12) To measure discharges at the main regulators and intake gates more accurately.
13) To use existing mobile pumps of the RID for limited areas where water shortage is serious, instead of supplying irrigation water by the gravity system.
14) To establish technology of farming and marketing to promote more widespread crop diversification in the WM dry season.
15) To construct regulating ponds.
16) To strengthen training courses that can contribute to practical water operation.

The above countermeasures will not be easy to implement. However, they are considered to be unavoidable problems. In terms of 1)-3), great progress is expected with revolution of information technology. This technology will provide tools for 4)-11). Information on canal networks and water operation facilities should be revised more frequently. Establishment of an information processing environment will be the first step. On the other hand, maintaining a balance between experience and analysis is also important to ensure a well-grounded water operation process with scientific background.

The main information on water management and hydrology is opened to the public at the homepage of RID (http://www.rid.go.th). RID organized the Office of Hydrology and Water Management in 1997. It enabled to collect and use data more effectively and practically than before. Availability of information on water management contributes to ownership and development of capable persons. Research achievements (Kasetsart University and ORSTOM, 1996, http://www.ku.ac.th/delta, Francois et al., 1999a, 1999b, 2001a and 2001b, Paul Consultant Co.Ltd. et al., 1999) are helpful to reconfirm existing conditions and determine alternative countermeasures. Information on drainage (Francois et al., 1997) will become more important for conservation of water resources.

In terms of 4)-7), some efforts have already begun to cope with water shortage, flood and environmental conservation. RIO-8 makes water allocation and cultivation plans for their command

area every year. But, they have not arranged the data for the respective lateral irrigation canals. In August 2000, RIO-8 re-calculated the water demand for the command area of respective lateral irrigation canal as shown in Table 6. The intake plan for the Manorom and Maharaj regulators requires counting of conveyance loss and direct intake from the main irrigation canals of the Chainat-Pasak and Chainat-Ayutthaya. In fact, in terms of conveyance loss, RIO-8 multiplies 1.4 for the command area of the Chainat-Pasak canal system, and 1.6 for other systems.

Stable supply of water to lateral irrigation canals is essential. A plan throughout the year is needed. To open and feedback information such as shown in Table 6 to the respective O/M Project Offices and farmers correspond as an Objectively Verifiable Indicator for output in the field of water management.

In terms of 8), more effective use of released water from the floating rice area should also be discussed. Reuse of irrigation water will contribute to water quality conservation (Yuyama et al., 1999). In terms of 14), the strengthening of drainage standards is needed, because field crops and vegetables are not as strong against inundation as paddy. In terms of 15), many spatial levels of ponds can be considered. These purposes include peak cut of discharge during flood, storage for supplementary irrigation during emergency situations at the planting stage in both early WM dry season and early WM wet season, and minimizing time lag of water traveling between supply and demand points (buffer function).

Some proposals to improve water management that the RID can carry out by her authority have arranged (Yuyama et al., 2003).

2 Decision support system for practical water operation

There are many difficulties in practical water operation. The RID makes water allocation and flood control plans every year. RID also has a daily reporting system on water operation and hydrology, and computer software to calculate water demands for water allocation planning, runoff discharge, flow conditions and so on. However, it is difficult to judge the reasonableness of water allocation planning and practical water operations perfectly. Every process of water operation cannot be automatic.

Therefore, the Members have started to develop a decision support system (DSS) for practical water operations (Pongsak et al., 2001, Yuyama et al., 2002). The decision-makers and all responsible persons will be able to obtain the latest summarized information easily. Sharing information and the thinking process between RID and farmers are important. A decision support system will contribute to fair water allocation planning and practical operation with accountability.

The target O/M Projects are Manorom, Chong Khae, Khok Krathiam, Roeng Rang and Maharaj located in the UEB of the Chao Phraya Delta. However, information is needed on the upstream dams and downstream areas of the Chao Phraya River. In order to learn from past trends, daily data from 1994 will be input into the database. The concepts of the system are as follows:

1) Contributions to water allocation planning and practical water operation of the main regulators throughout the year (for stable and efficient water supply by saving water at every spatial and temporal levels).
2) Combination of monitoring, analysis and experience (Improvement of man-machine interface).
3) Common ownership of water management process by RID HO, RIO, O/M Project Office and Hydrology Center (Establishment of information networking; Opening daily information at the lateral canal level and above).
4) Effective use of existing computer software on water management and improvement in hydrology and water management databases.
5) Paying more attention to drainage systems.
6) Use of Geographical Information System (GIS) and Remote Sensing (R/S) Technology.

Table 6 Weekly water allocation plans at lateral irrigation canals

Date	Manorom Project											Chong Khae Project											Khok Krathiam Project						Roeng Rang Project			
	1R	2R	3R-1	3R-2	3R	4R	5R	6R	7R	8R	Total	9R	10R	11R	12R	13R	14R	16R	17R	1L	2L	3L	Total	18R	19R	20R	21R	22R	Total	23R	24R	25R	Total
29 Jan.- 4 Feb.	0.015	0.019	0.003	0.005	0.051	0.019	0.088	0.067	0.011	0.052	0.329	0.220	0.004	0.003	0.094	0.095	0.101	0.047	0.015	0.001	0.004	0.003	0.589	0.087	—	0.003	0.491	0.197	0.778	0.319	—	0.009	0.328
5-11 Feb.	0.021	0.027	0.004	0.008	0.058	0.027	0.097	0.080	0.016	0.063	0.400	0.256	0.006	0.005	0.097	0.097	0.106	0.068	0.021	0.002	0.006	0.004	0.669	0.100	—	0.004	0.516	0.213	0.834	0.374	—	0.013	0.387
12-18 Feb.	0.022	0.028	0.004	0.008	0.059	0.028	0.098	0.081	0.017	0.064	0.408	0.261	0.007	0.005	0.097	0.098	0.106	0.071	0.022	0.002	0.006	0.004	0.679	0.101	—	0.005	0.519	0.215	0.839	0.377	—	0.014	0.391
19-25 Feb.	0.152	0.199	0.026	0.057	0.187	0.194	0.294	0.345	0.116	0.267	1.837	0.992	0.047	0.036	0.144	0.150	0.211	0.496	0.156	0.012	0.045	0.030	2.318	0.366	—	0.032	1.061	0.551	2.010	1.554	—	0.099	1.653
26 Feb.- 4 Mar.	0.276	0.361	0.048	0.103	0.309	0.352	0.483	0.596	0.210	0.462	3.200	1.696	0.085	0.066	0.188	0.199	0.310	0.900	0.283	0.022	0.081	0.055	3.866	0.618	—	0.059	1.580	0.871	3.129	2.695	—	0.180	2.875
5-11 Mar.	0.355	0.464	0.061	0.132	0.387	0.452	0.602	0.756	0.270	0.585	4.064	2.139	0.109	0.085	0.217	0.231	0.373	1.157	0.364	0.028	0.104	0.071	4.877	0.775	—	0.075	1.900	1.070	3.820	3.419	—	0.232	3.651
12-18 Mar.	0.477	0.623	0.083	0.178	0.507	0.608	0.785	1.003	0.363	0.776	5.402	2.824	0.146	0.114	0.261	0.280	0.470	1.555	0.489	0.038	0.140	0.095	6.412	1.018	—	0.100	2.398	1.378	4.895	4.536	—	0.313	4.849
19-25 Mar.	0.557	0.729	0.096	0.208	0.586	0.710	0.907	1.167	0.425	0.902	6.288	3.278	0.171	0.134	0.290	0.312	0.534	1.819	0.572	0.045	0.163	0.111	7.427	1.179	—	0.117	2.727	1.582	5.605	5.277	—	0.366	5.643
26 Mar.- 1 Apr.	0.806	1.054	0.140	0.301	0.832	1.027	1.281	1.670	0.615	1.291	9.016	4.675	0.247	0.193	0.379	0.411	0.733	2.630	0.827	0.064	0.236	0.161	10.557	1.678	—	0.169	3.747	2.215	7.809	7.546	—	0.530	8.076
2-8 Apr.	0.964	1.261	0.167	0.359	0.987	1.229	1.520	1.990	0.735	1.538	10.750	5.567	0.295	0.231	0.436	0.474	0.859	3.145	0.989	0.077	0.282	0.193	12.549	1.953	—	0.198	4.312	2.564	9.028	8.933	—	0.630	9.563
9-15 Apr.	1.182	1.546	0.205	0.441	1.202	1.507	1.848	2.432	0.901	1.880	13.144	6.793	0.362	0.283	0.514	0.561	1.034	3.857	1.212	0.094	0.346	0.236	15.294	2.364	—	0.241	5.152	3.085	10.842	10.913	—	0.772	11.686
16-22 Apr.	1.095	1.432	0.190	0.408	1.116	1.395	1.716	2.255	0.835	1.743	12.185	6.302	0.335	0.262	0.483	0.526	0.964	3.572	1.123	0.087	0.321	0.219	14.194	2.165	—	0.220	4.746	2.833	9.966	10.119	—	0.715	10.834
23-29 Apr.	0.898	1.175	0.156	0.335	0.922	1.145	1.421	1.857	0.685	1.435	10.030	5.198	0.275	0.215	0.412	0.448	0.807	2.931	0.921	0.072	0.263	0.179	11.723	1.728	—	0.175	3.851	2.278	8.032	8.343	—	0.587	8.930
30 Apr.- 6 May	0.633	0.827	0.110	0.236	0.661	0.806	1.017	1.319	0.482	1.020	7.110	3.690	0.194	0.152	0.317	0.342	0.595	2.064	0.649	0.051	0.185	0.126	8.364	1.261	—	0.126	2.890	1.686	5.963	5.640	—	0.393	6.034
7-13 May	0.662	0.866	0.115	0.247	0.689	0.844	1.061	1.378	0.505	1.065	7.431	3.854	0.203	0.159	0.327	0.354	0.618	2.160	0.679	0.053	0.194	0.132	8.731	1.320	—	0.132	3.010	1.760	6.222	5.900	—	0.412	6.312
14-20 May	0.705	0.922	0.122	0.263	0.732	0.898	1.125	1.465	0.537	1.133	7.902	4.095	0.216	0.169	0.343	0.371	0.652	2.300	0.723	0.056	0.206	0.141	9.271	1.406	—	0.141	3.186	1.869	6.601	6.282	—	0.440	6.721
21-27 May	0.721	0.943	0.125	0.269	0.747	0.919	1.149	1.498	0.550	1.158	8.077	4.185	0.221	0.173	0.348	0.377	0.665	2.352	0.739	0.058	0.211	0.144	9.472	1.438	—	0.144	3.251	1.909	6.742	6.424	—	0.450	6.874
28 May- 3 Jun.	0.667	0.873	0.116	0.249	0.695	0.850	1.069	1.389	0.509	1.074	7.489	3.884	0.204	0.160	0.329	0.356	0.662	2.177	0.684	0.053	0.195	0.133	8.798	1.330	—	0.133	3.032	1.773	6.269	5.947	—	0.416	6.363
4-10 Jun.	0.545	0.713	0.094	0.203	0.574	0.695	0.884	1.142	0.416	0.883	6.148	3.193	0.167	0.131	0.285	0.307	0.525	1.779	0.559	0.044	0.160	0.109	7.257	1.127	—	0.112	2.613	1.515	5.366	4.710	—	0.327	5.037
11-17 Jun.	0.494	0.646	0.086	0.184	0.524	0.630	0.807	1.039	0.377	0.803	5.591	2.908	0.151	0.118	0.267	0.287	0.484	1.613	0.507	0.039	0.145	0.099	6.618	1.025	—	0.101	2.405	1.386	4.917	4.259	—	0.294	4.553
18-24 Jun.	0.403	0.527	0.070	0.150	0.435	0.514	0.670	0.854	0.307	0.661	4.592	2.396	0.124	0.097	0.234	0.250	0.411	1.316	0.413	0.032	0.118	0.081	5.472	0.844	—	0.082	2.036	1.157	4.119	3.471	—	0.237	3.709
25-30 Jun.	0.356	0.465	0.062	0.133	0.388	0.454	0.599	0.758	0.271	0.587	4.073	2.130	0.109	0.085	0.217	0.231	0.374	1.161	0.365	0.028	0.104	0.071	4.876	0.751	—	0.073	1.845	1.039	3.709	3.075	—	0.209	3.284
Total (MCM)	7.23	9.46	1.25	2.70	7.62	9.21	11.75	15.14	5.51	11.71	81.58	42.48	2.21	1.73	3.78	4.07	6.96	23.59	7.41	0.58	2.12	1.44	96.37	14.83	—	1.47	34.48	19.96	70.74	66.33	—	4.60	70.93

Remark 1) Unit is m^3/s.

2) Conveyance loss is not counted.

3) There is no allocation plan for 15R because it is under rehabilitation.

4) Allocation for 19R is included in 18R.

5) Allocation for 24R is included in 23R.

The system will consist of four sub-systems namely monitoring, database, analysis, and reference information as shown in Table 7. Accurate monitoring of the existing conditions and sharing summarized information is essential. Promotion of digitizing and networking will save time and personnel expenses. The database sub-system makes the preparation of input data for any kind of analysis easy. Existing software such as AISP (Acres Irrigation Support Package; Acres International Ltd., 1999, Choolit, 1999) and flow analysis (IEC, 1995, Yoshino et al., 1997) can be used.

Table 7 Constitution of sub-system for DSS

<Monitoring> Storage and release of reservoir/dam Rainfall Water level Discharge Salinity Cropping area Inundation condition Operational condition of facilities	<Database> River and canal network Hydrology database Water management database Facility database List of important reports and papers
<Analysis> Water requirement analysis Runoff analysis Calculation of discharge at regulator Flow analysis Water balance analysis	<Reference information> Flow of information on water operation Organization and responsible persons Plan of cultivation and water allocation Water requirement by respective crop Weather forecast Arrangement of problems (past, present and expected in future) Questions and Answers

The process of the development is very important, because without participation, understanding and agreement among future users, the system will not actually function. Therefore, the Members have repeated discussions and decided a schedule and the personnel to develop the system. Table 8 outlines them. The points and content of monitoring were carefully chosen. Table 9 shows the daily monitoring points and content of each point. The system will be completed by trial and error with continuous modification to ensure the sustainable use.

Computers needed for networking were already installed as shown in Fig. 11. Two LCD projectors were also installed to display O/M information on the screen. However, according to the data communication test using a telephone line, the communication between RID HO and local offices was not always good. The number of telephone lines at the concerned offices is not sufficient. These problems must be solved.

Procedure to improve data collection for the DSS is as follows:

1) Add important water operation information that was missing.
2) Type O/M data sheet by Microsoft EXCEL at each O/M Project Office and send to RIO-8 by facsimile.
3) Send the above information by attached E-mail file.
4) Improve the digital reporting method.
5) Hydrology Center No. 5 at Chainat should send needed daily information to RIO-8 and RID HO through networking.
6) Improve water management and hydrology database to receive collected data directly.

The Members have already added the information of missing facilities and corrected careless mistakes in the daily O/M data sheet. The digital sheet made by Microsoft EXCEL was prepared. By September 2001, Manorom and Khok Krathiam O/M Projects began to use the digital sheet. The Manorom O/M Project also started to send reports to RIO-8 and RID HO by attached of E-mail file. This

step was needed, because all O/M Projects were not familiar with digital reporting. A new method to input data and send it to RIO-8 and RID HO was developed (Somnuk, 2002). This method uses Adobe Acrobat Ver. 5.0 and can minimize the file size of data transfer by E-mail. This activity corresponds to 4) of the above-mentioned procedures and this method will be expanded to other O/M Projects and the Hydrology Center No. 5.

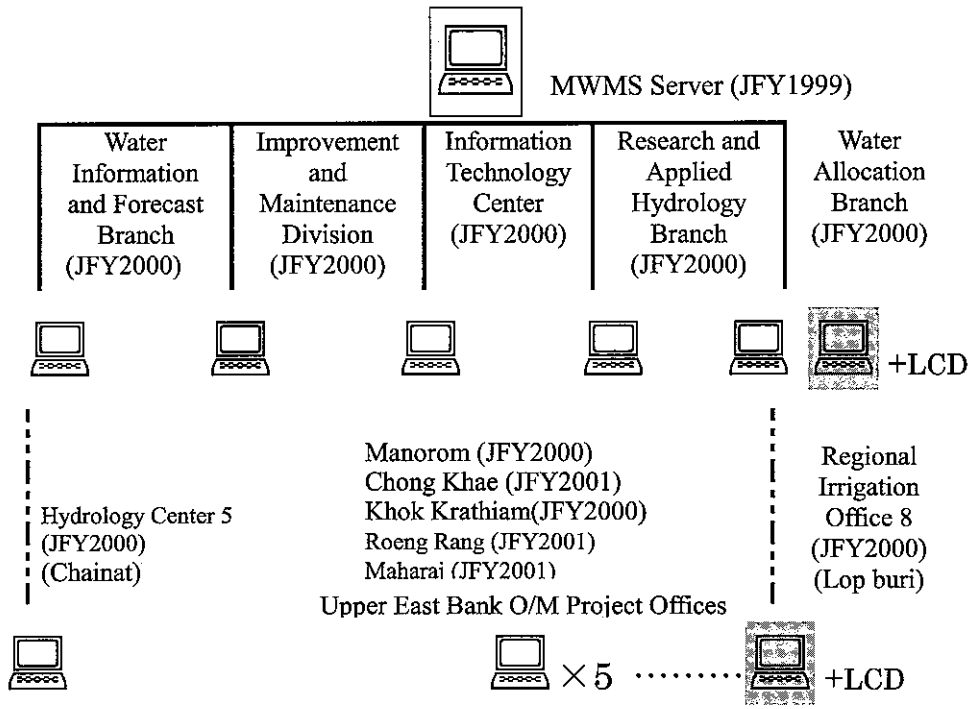


Fig. 11 Computer networking for DSS

On the other hand, some collected information has been input into GIS layers to better understand water management visually (Ogawa et al., 2001). Fig. 12 shows an example of a GIS layer. The point data includes dimensions of facilities, digital pictures, records of water operation and so on. The line data means river and canals. Location of some facilities was identified by GPS. GIS software of *ArcView* and *ArcInfo* (ESRI Ltd.) was used.

3 Monitoring of rainfall with an electromagnetic type rainfall gauge

It is very difficult to catch all rain with a normal topple type rainfall gauge during heavy rainfall. The electromagnetic type rainfall gauging system is superior for catching continuous rainfall less than 150 mm/h with an error of 3 %. The authors installed an electromagnetic gauge at Water Master Office No. 2, Khok Krathiam O/M Project on 20 July 2000. The gauge is Model B0410 of YOKOGAWA DENSHIKIKI Co. Ltd.. It can monitor rainfall at any interval such as 10 minutes and one hour. Data are stored in the data logger and collected by a PC card. Fig. 13 shows the inside of the rainfall gauge.

The Members analyzed data between August 2000 and September 2001. The Members focused on rainfall characteristics of one series of rainfall, namely independent rainfall. Here, one series of rainfall was defined as continuous rainfall with a quantity of at least 0.5 mm/hr. The Members chose a rainfall event that accumulated rainfall equal to or more than 5.0 mm. There were 45 events measured.

Table 8 Plan for development of DSS

Item of activity	Schedule		Equipment
	from	to	
(1) Preparation and determination of concept	05/2001	08/2001	
(2) Total system design	09/2001	12/2001	computer
(3) Work for development			
a. Improvement of database			
Input of water operation data from 1994 to present	07/2000	09/2002	computer
Input of hydrology data from 1994 to present	07/2000	09/2002	computer
Measurement of loation of water operation facility and hydrology station by GPS	11/2000	12/2002	GPS
Take pictures of water operation facility and hydrology station	07/1999	12/2002	camera
Establish efficient collection of water operation and hydrology information (digital format)	05/2001	03/2002	computer
Arrangement of facility information	05/2001	09/2002	computer
Improvement of water management database (for easy input and edit)	05/2001	12/2002	computer
Improvement of hydrology database (for easy input and edit), and combine with water management database if needed	05/2001	12/2002	computer
b. Information networking			
Computer networking within RID HO	06/1999	06/2000	computer
Computer networking between RID HO and remote offices	05/2001	03/2002	computer
Data communication test by TOT line and Internet	10/2000	01/2002	computer
c. Arrangement of water management information by GIS	11/2000	09/2003	GIS software, computer, scanner, plotter, digitizer
(4) Application to the UEB of the Chao Phraya Delta			
a. Water allocation planning throughout the year	07/2001	12/2003	
b. Daily collection of water operation and hydrology information and input into database	03/2002	03/2004	computer
c. Effective use of water management software			
Improvement of water allocation by the use of the AISP Project Model	06/2001	03/2004	computer
Improvement of water operation by the use of NUFLOW in the Chainat-Pasak canal	10/2001	03/2004	computer
Development of runoff analysis model in left bank of the Chainat-Pasak canal	05/2001	09/2002	computer, planimeter, scanner
Estimation of traveling time between the upstream dams and Chao Phraya Diversion Dam	07/2001	12/2002	computer, planimeter,
Calculation of water requirement	10/2001	09/2002	computer
Calculation of water balance	06/2002	03/2003	computer, planimeter, scanner
d. Arrangement of regulator operation guidelines for the Chainat-Pasak canal	10/2002	09/2003	computer

Table 9 Daily information for DSS

	Storage Volume	Water level	Discharge	Salinity	Operation
<Reservoir dam>					
Bhumibol	O	O	O***		
Sirikit	O	O	O***		
Pasak	O	O	O***		
<Chao Phraya river>					
Nakhon Sawan (C2)		O	O		
Chao Phraya Diversion Dam (C13)		O*	O		O
Singburi (C3)		O			
Ang Thong (C7A)		O	O		
Bangsai (C29)		O			
RID Pakkret (C22)		O		O	
RID H.O. (C12)		O		O	
Memorial Bridge (C4)		O		O	
River mouth (Samut Prakan)		O**			
<Pasak river>					
Ban Muang Nua (S9)		O	O		
Kaeng Khoi (S2)		O	O		
Rama VI Diversion Dam (S26)		O*	O		O
Panchama Thirat Uthit Hospital (S5)		O			
<Lopburi river>					
Pak Maenam Lopburi regulator		O*	O		O
Pho Kao Ton regulator		O*	O		O
Wat Khang Khao (L2B)		O			
<Chainat Pasak Canal>					
Manorom regulator		O*	O		O
Chong Khae regulator		O*	O		O
Khok Krathiam regulator		O*	O		O
Roeng Rang regulator		O*	O		O
<Chainat Ayutthaya Canal>					
Maharaj regulator		O*	O		O
Ban Tuk regulator		O*	O		O
Bang Chom Sri Siphon		O*	O		O
<Drainage regulator>					
Bang Kharm (Chong Kae)		O*	O		O
Bang Li (Khok Krathiam)		O*	O		O
Wat Manee (Khok Krathiam)		O*	O		O
Klong Ta Mek (Khok Krathiam)		O*	O		O
Bang Khum (Roeng Rang)		O*	#		O
Ko Lerng (Roeng Rang)		O*	#		O
Bang Chom Sri (Maharaj)		O*	#		O
Ban Rai (Maharaj)		O*	#		O
Kao Chang (Maharaj)		O*	#		O
Bang Khung (Maharaj)		O*	#		O
Klong Noi (Maharaj)		O*	#		O
Wat U-lom (Maharaj)		O*	#		O
Bang Khaeo (Maharaj)		O*	#		O
<O/M>					
Monorom O/M Project area		O	O		O
Chong Khae O/M Project area		O	O		O
Khok Krathiam O/M Project area		O	O		O
Roeng Rang O/M Project area		O	O		O
Maharaj O/M Project area		O	O		O

Remark: O* indicates monitoring at both upstream and downstream. O** indicates the estimated tidal level. O*** indicates the release discharge. # is needed for the water balance analysis.
<O/M > includes water level and discharge at intake of lateral canals.

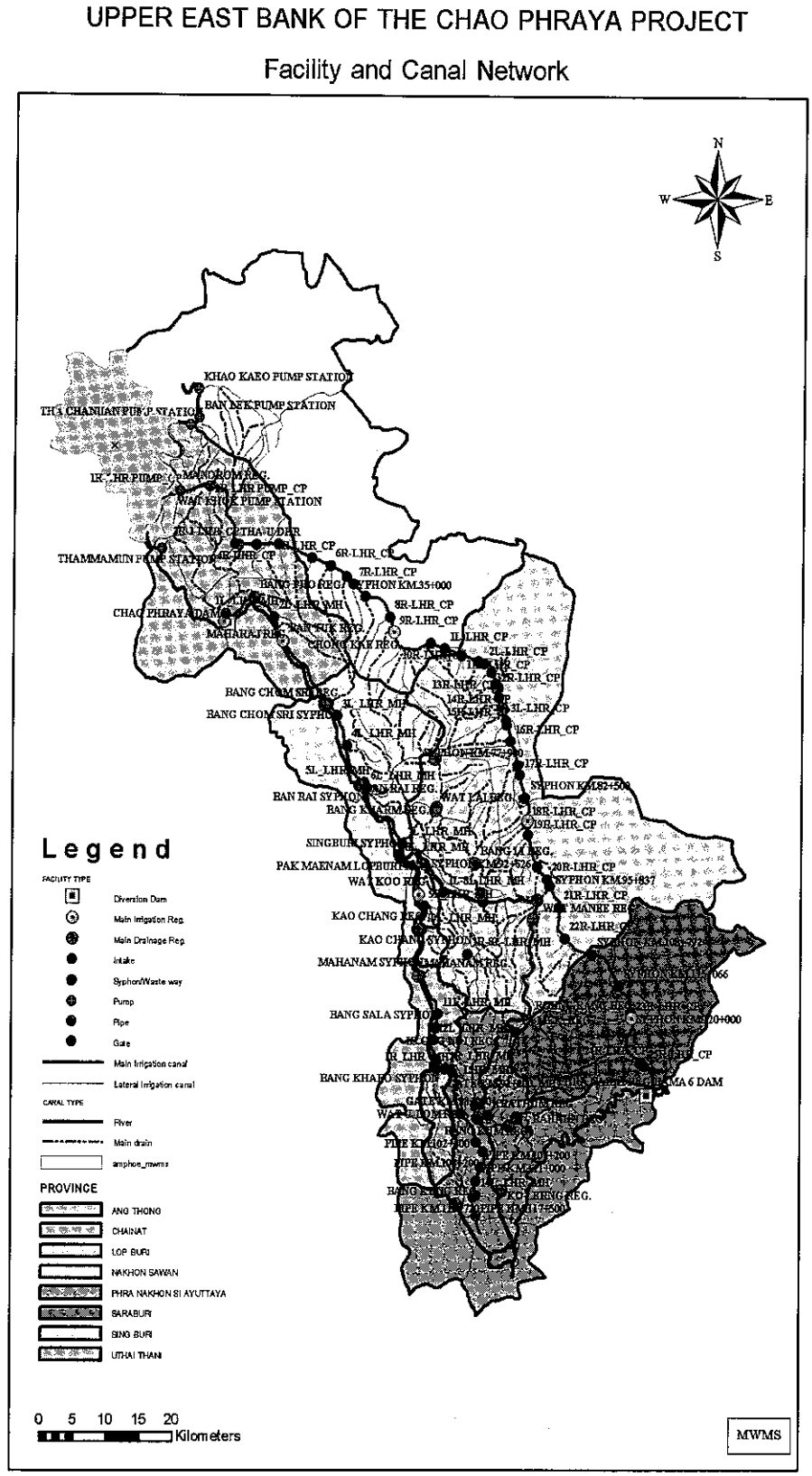


Fig. 12 Example of GIS layer

Fig. 14 shows the frequency of rainfall events at the peak time. It is remarkable that it often rains between 15:00 and 20:00 and in the midnight hours. It is reasonable to monitor the previous day's rainfall at 6:00 and to count effective rainfall for the irrigation plan on that day.

Fig. 15 shows how long one series of rainfall continues. The rainfall events in which the duration was longer than 6 hours were only 3 events, or 13 % of the total events. Fig. 16 shows the frequency of accumulated rainfall. More than 70 % of rainfall stopped within 2 hours.

In addition, the maximum intensity of rainfall was as follows:

3) Maximum daily rainfall: 84 mm (on 27 September 2000)
4) Maximum hourly rainfall: 70.5 mm (19:40-20:40 on 27 September 2000)
5) Maximum 10 minute rainfall: 20.5 mm (19:40-19:50 on 27 September 2000)

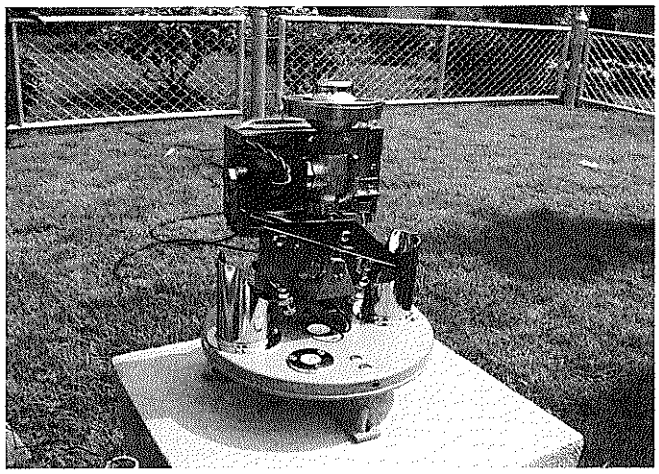


Fig. 13 Inside the electromagnetic type rainfall gauge

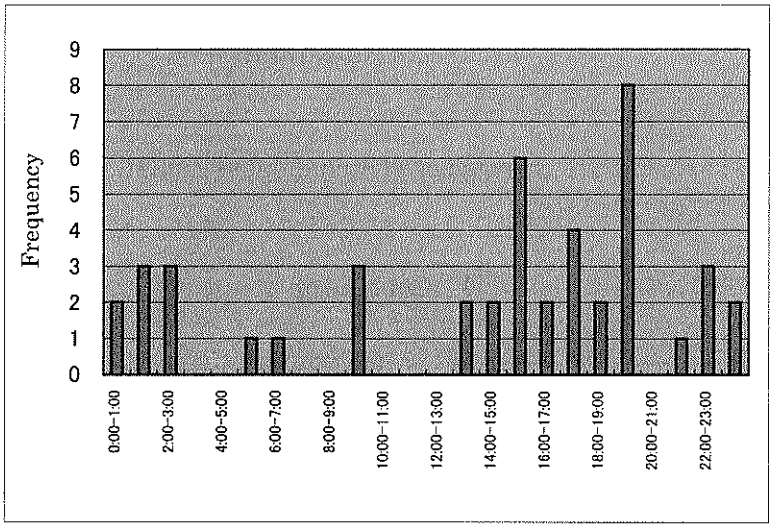


Fig. 14 Frequency of peak time of rainfall

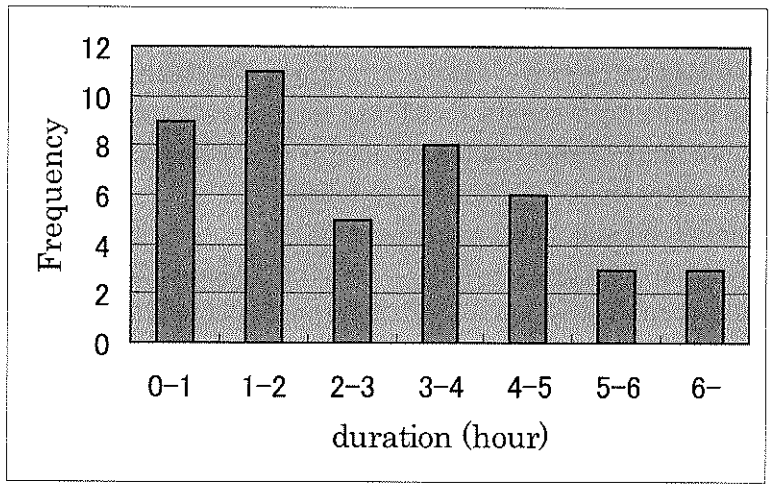


Fig. 15 Frequency of duration of rainfall

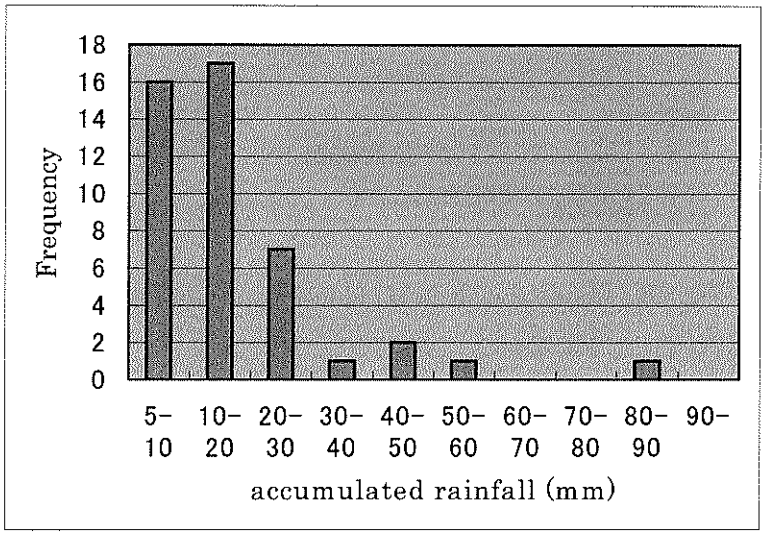


Fig. 16 Frequency of accumulated rainfall

VI Conclusion

The Members have promoted activities in the MWMS project based on PDM (Project Design Matrix) and PO for three years. Their goal is to improve water allocation planning and practical operation in the UEB of the Chao Phraya Delta. They confirmed the existing irrigation and drainage systems. At the same time, the present situation and problems of water management in the delta area were reviewed. Many ideas to improve water management were arranged. Modern technology and Thai customs need to be mixed well to determine the best sustainable agricultural system, including water management. The members have already begun to develop a DSS for practical water operation as a tool for man-machine interface to promote water management with accountability. Having information in common and sharing the thinking process between RID and other concerned authorities are important for determing more appropriate water management and improving human resources. The expected

output in the water management field under the MWMS project is as follows:

DSS for the operation of main facilities in the UEB of the Chao Phraya Delta is developed, and as a result of it, related RID offices and farmers can compare the planed and actual data of water allocation.

Throughout the development of DSS, digitized O&M data in the UEB of the Chao Phraya Delta and related hydrology data are arranged and opened daily throughout the network. The conditions of water allocation will be broken down to the lateral irrigation canal level. If the farmers understand the weekly water allocation plan at the lateral irrigation canal level for the following WM dry season in advance, they can make cultivation plans without risk even though the water allocated is not sufficient. The stability of water allocation is actually important. This stability may decrease excess intake and storage in the field and also contribute to recovering the reliance between farmers and RID.

Farming and water management in the Chao Phraya Delta is changing rapidly. Now, the Chao Phraya Delta, the rice bowl of Thailand, looks like an active eco-museum of rice farming. Visitors can find almost all cultivation stages of rice throughout the year. Corresponding to changes in background, re-allocation of water resources, rehabilitation of aged facilities, construction of facilities, improvement in water operation, and promotion of PIM are actually sought (Charoon et al., 1993, Siripong, 1997). The UEB of the delta has great potential for development (NESDB, 1990). The authors anticipate the sustainable prosperity of the area through good water management.

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チャオプラヤデルタ上流東岸域における水配分計画と実際の水利施設操作の改善

ータイ国水管理システム近代化計画における活動ー

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要約

日本のプロジェクト方式技術協力「タイ国水管理システム近代化計画（MWMS）」が，１９９９年４月から５カ年間の予定で，国際協力事業団の協力のもと，王室潅漑局及び農業普及局によって実施されている。プロジェクトの目標の１つは，効率的な水管理を通して乾期に必要な水資源を安定的に確保することにある。多岐にわたるプロジェクト活動の中で，水管理分野は，チャオプラヤデルタ上流東岸域の水配分計画と実際の水利施設操作法の改善に焦点を当てている。現状分析を踏まえ，幹線用水路から支線潅漑用水路への週毎の水配分計画を関係者が共有することを最優先課題とした。このため，モニタリング，データベース，解析，参考情報の４つのサブシステムからなる水管理意志決定支援システムの開発を開始した。このシステムにより，水管理の意志決定者が要約された情報を容易に入手し説明責任のある形で水管理がなされ，水利用の安定性が増す。また，情報の共有化により農家と王室潅漑局との信頼関係が強化される。

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キーワード：水管理，意志決定システム，MWMS，王室潅漑局，タイ国