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Project Water Requirement in the Yamato Plain Land Improvement District —Design and Management of Large Scale Irrigation System (I)—

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Abstract

This paper describes the design and water management of large scale irrigation systems, specifically the estimation of the project water requirement for the rehabilitation scheme of the irrigation system in the Yamato Plain Land Improvement District (abbreviated to YPD) of Nara prefecture. YPD was organized to be responsible for the operation and maintenance of the major subdivision of the Totsugawa-Kinokawa Integrated Development Project (abbreviated to TKP) in 1961.

30 years have passed since the completion of TKP. Rehabilitation of the whole irrigation system is needed due to degradation of irrigation efficiency caused by superannuation and the change of water users' situations caused by increasing part-time farmers and aging farmers.

The purpose of the system rehabilitation is basically to save labor costs and increase irrigation efficiency. On the other hand, to meet the needs of increment of municipal water use in expanding urban areas, implementation of the system rehabilitation is necessary, in addition, it is needed to provide water front parks and recreation facilities.

The water source of this system consists of water developed by TKP and old local water resources i. e. water diverted from natural streams, many ponds and ground water. The water distribution system is also divided into two systems: the YPD system and the local irrigation system, including natural streams. The simplification and unification of the distribution system is also required for the rehabilitation.

At first, the project water requirement must be estimated based on the existing water supply system and the water users' situation. The estimation of the project water requirement by using the CB method is useful in this case. Then, comparing with the estimated values and data of existing water supplied, an appropriate project water requirement is determined. The rahabilitation scheme will be composed, based upon the appropriate water requirement.

I. Introduction

The Totsugawa-Kinokawa Integrated Development Project (abbreviated to TKP) was completed in 1961. TKP consists of augmentation of water resources (four reservoirs and large scale transmountain water transfer), unification of the old diversion dams, power generation, construction of water transmission and delivery systems and other water conservation structures. The Yamato Plain Land Improvement District (abbreviated to YPD) was organized to be responsible for operating and maintaining the TKP's subdivision (called the Yoshino Bunsui) which is located at the Yamato Plain in Nara Prefecture of central Japan.

Rapid urbanization and mixed habitations in YPD's command area caused many problems, that is, water pollution, siltation, increment of peak run-off and so on. The

superannuation of the irrigation facilities brought many difficulties in operation and maintenance and caused increasing defectiveness of the water. On the other hand, increment of municipal water use needs new water resources but it is quite difficult to find out new water resources. It is considered that the rehabilitation of YPD irrigation systems is one of the possible solutions for future demands.

This paper reports on the estimation of the project water requirement by using the CB method and on discussion of the results comparing with the water allocation to YPD, today.

II. The Totsugawa-Kinokawa Integrated Development Project (TKP)

The Totsugawa-Kinokawa Integrated Development Project (TKP)[1] was established as a national enterprise by the Ministry of Agriculture, Forestry and Fisheries (abbrebiated to MAFF) in 1952. TKP was mainly schemed to divert water from the Yoshinogawa River into Yamato Plain using transmountain water transfer.

For meeting needs of water users in the lower basin of the Yoshinogawa River (in which the Yoshinogawa River is called the Kinokawa River in Wakayama Prefecture), it has been inevitable to transfer supplemental water from the Totsugawa River into the Kinokawa River. To carry out the scheme four dams and reservoirs, namely Ohsako, Tsuburo, Yamada and Sarutani, were constructed (Fig. 1, Table 1). Two reservoirs, namely Ohsako and Tsuburo are for common use in both Nara and Wakayama Prefectures, and two reservoirs, namely Yamada and Sarutani, are for Wakayama Prefecture use only.

The Yoshino Diversion Scheme (called the Yoshino Bunsui)[2] is the major TKP

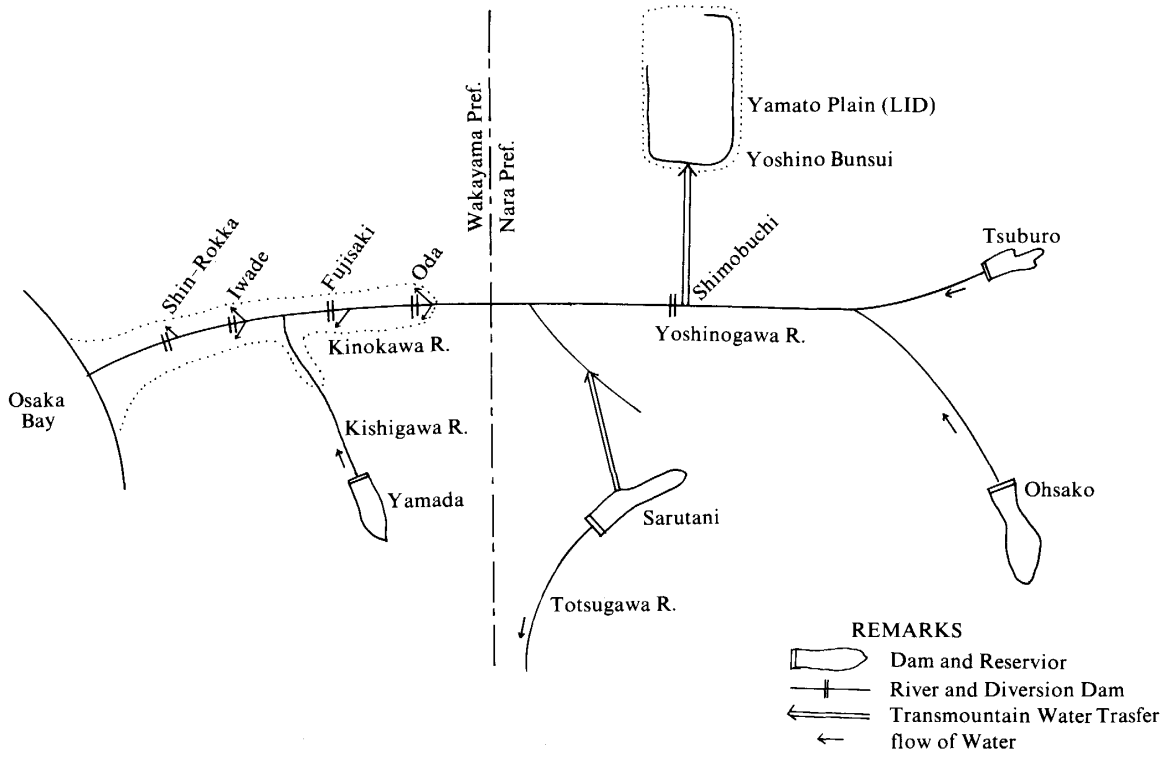

Fig. 1 The Totsugawa-Kinokawa Integrated Development Project

Table 1. Dam and reservoir data

Dam and Reservoir	River	Structure Type	Effective Storage Capacity	Surface Area	Release Flow Rate
			million m^3	ha	m^3/s
Ohsako	Yoshinogawa	arch	26.7	107	20.0
Tsuburo	Tsuburogawa	gravity	24.6	150	11.0
Yamada	Kishikawa	gravity	3.4	34	1.7
Sarutani	Totsugawa	gravity	17.3	100	16.7

sub-division. The Yoshino Bunsui diverts water at Shimobuchi Diversion Dam at a maximum flow rate of 10.977 m^3/s (9.907m^3/s for irrigation and 1.070 m^3/s for municipal water), then conveyed to Yamato Plain in which the irrigaion area is 10, 881 ha.

At the entrance to Yamato Plain, the conveyance canal is divided into two main canals, the Main Western Canal and Main Eastern Canal. The distribution system of the Yoshino Bunsui consists of 26 sub-divisions which take water at each off-take to lateral and sub-lateral. All laterals and sub-laterals are constructed by Nara Prefecture and YPD is responsible for operating, maintaining and managing the system.

III. The Yoshino Diversion System organization (the Yoshino Bunsui)

The Yoshino Diversion system is the most major sub-division of TKP. The Shimobuchi diversion Dam and main conveyance canal up to the head of YPD distribution system are under the control of MAFF. MAFF is also responsible for the operation and maintenance of the Ohsako dam and the Tsuburo dam. For equitable water management among water users in both Nara Prefecture and Wakayama Prefecture, these three structures must be controlled by MAFF.

The main facilities of the Yoshino Bunsui are under the control of YPD, in Which two main canals, 26 off-takes, 10 checks and 4 gauging stations are included. YPD as the representative of farmers in the command area has the functions not only on operation, maintenance and management of the organization but also on lobbing, negotiation and application to MAFF and local governments for the system rehabilitation and/or all water matters related to YPD.

Laterals, sub-laterals and tertiaries are controlled by local irrigation associations and rural communities respectively. Old and local water sources such as ponds and natural streams are also mixed with the Yoshino Bunsui in this level. Many local irrigation associations and rural communities in which beneficial farmers cooperate, are responsible for maintenance and operation of laterals, sub-laterals and old local facilities.

IV. Procedure and determination of designed water requirement in the Yoshino Diversion Scheme (the Yoshino Bunsui)

The procedure and determination of the water requirement which was designed for the Yoshino Bunsui by MAFF are delineated as follows[1,2].

1. Design Water requirement

Irrigation season (from June 15 to Sept. 15, 93 days) is divided into two stages: (1) puddling and transplanting stage (from June 15 to 22, 8 days), and (2) normal growing stage (from June 23 to Sept. 15, 85 days). The acreage of designed irrigation area is 10, 881 ha. Water requirements are calculated at each stage, and summed up.

(1) Puddling and transplanting stage

The water requirement at this stage consists of puddling water and daily water depression after puddling. Puddling is done in 8 days rotation. A net water requirement (P in depth) for puddling is 100 mm, and the daily water depression (D_1 in depth) is 6.5 mm/day. Thus, the daily water requirement (W_1 in depth) is calculated as:

$$W_1 = A \frac{P + (i-1) D_1}{8} \quad (1)$$

where A : acreage of irrigation area

i : 1 to 8, days after puddling.

The daily water requirement is maximum at $i=8$ (the last day of this stage), and it is 18.2 mm/day. The total volume and average daily water requirement are calculated as 13.4 million m^3 and 15.4 mm/day respectively.

(2) Normal growing stage

The water requirement at this stage is calculated by the daily water depression. A standard value of the daily water depression is appropriately determined by the observed data and the water depressions of each growing season can be determined by multiplying the standard value by seasonal factors (Table 2). The total volume of the water requirement is calculated as 103.8 million m^3. The maximum daily water requirement is 13.7 mm/day.

Table 2. Seasonal daily water depression in mm/day

Jun. 15–24	Jun.25–Jul.4	Jul. 5–14	Jul. 15–24	Jul.25–Aug.3	Aug. 4–13	Aug. 14–23	Aug.24–Sept.2	Sept. 3–12	Sept. 13–15	Mean
6.5	6.9	9.0	13.7	11.8	12.0	13.3	11.5	9.5	9.1	10.4

2. Effective rainfall

Effective rainfall was estimated through the following procedure: by using the rainfall data from the irrigation season of 1926 to 1948 (23 years), the year 1944 was judged the design year for a 10 years return period. That rainfall in 1944 was the second least. The effective rainfall is defined as 80 % of the daily rainfall and the daily rainfall (R) is neglected less than 1 mm and if R is larger than 50 mm, R = 50 mm. The total effective rainfall is 266 mm by summing up daily effective rainfall.

3. Net and gross water requirements

The net water requirement was 88.2 million m^3 subtracting total effective rainfall of

29.0 million m³ from the total water requirement of 117.2 million m³ (13.4+103.8). The gross water requirement was 94.4 million m³, including water distribution loss of 7 % (Table3).

Table 3. Water requirement in million m³

Water Requirement			Effective	Net Water	Gross Water
Puddling S.	Normal S.	Total	Rainfall	Requirement	Requirement
13.4	103.8	117.2	29.0	88.2	94.4

4. *The total required volume for the Yoshino Bunsui*

The water sources consist of old and local water resources diverted from streams, ponds and ground water. Water diverted from ponds is estimated at 14.9 million m³ of the total ponds' storage. Water diverted from streams is estimated as follows: stream flow is stored in a pond and supplied through the pond, which is calculated from daily rainfall. Summing up the daily stream flow, the total water diverted from streams is estimated at 20.6 million m³ (1.4 times of total ponds' storage). The ground water is neglected because of its small quantity (it is designed so as to disuse the ground water).

Thus, the total required volume for the Yoshino Bunsui is estimated at 56.4 million m³, subtracting the water diverted from ponds and streams from the net water requirement, and including water conveyance loss of 7 % (Table 4).

A solid line in Fig. 2 shows the water allocation to the Yoshino Bunsui. The maximum flow rate is 9.9 m³/s at the puddlig stage. A broken line shows the actual diversion rate in 1978, and the total diverted volume is 56.2 million m³.

Table 4. Required volume of Yoshino Bunsui in million m³

Net Water Requirement	Ponds	Streams	Yoshino Bunsui
88.2	14.9	20.6	56.4

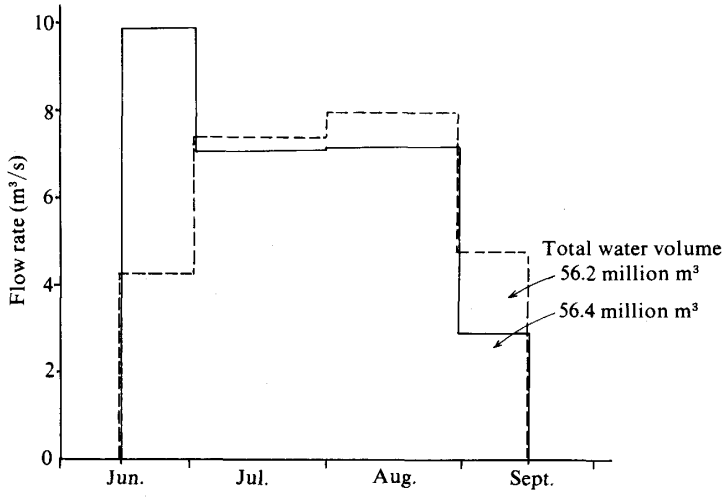

Fig. 2 Water allocation to the Yoshino Bunsui (solid line) and actual diversion rate (broken line) in 1978

V. Estimation of the project water requirement

Large scale irrigation projects such as the Yoshino Bunsui usually have a very complicated water reuse system of agricultural return flow. The old and local distribution canals in the YPD command area collect discharge of the Yoshino Bunsui water from the upstream paddies and then downstream farmers automatically reuse the return flow.

The CB method[3] developed by M. Okamoto is useful to estimate the project requirements for large scale paddy irrigation projects which contain the complex reuse system[4,5,6]. Fig. 3 shows the results of the analysis of a block diagram of YPD reuse system. In this figure, the three block types, CB, RB and NB Blocks are characterized as follows:

CB Blocks contribute to the flow rate (Q) at head works by the daily water depression,

RB Blocks contribute to the (Q) by the net consumption (evapotranspiration),

NB Blocks have no contribution to (Q).

(1) The maximum project requirement at normal growing stage

Under the condition that the daily water depression are 20 mm/day (Case 1) and 15 mm/day (Case 2), the net consumption is 7 mm/day and the distribution loss is 20 %, the areas of CB, RB, NB Blocks are calculated in Table 5. from Fig. 3. The flow rates (Q) at head works which show the maximum project requirement at normal growing stage are :

In Case 1 (20 mm/day of daily water depression),

$$Q = (2769 \times 7 + 6489 \times 20 - 81 \times 13) / 86400 \times 1.2 = 20.6 \ (m^3/sec).$$

In Case 2 (15 mm/day),

$$Q = (3032 \times 7 + 6374 \times 15 - 81 \times 8) / 86400 \times 1.2 = 16.1 \ (m^3/sec).$$

Table 5. Total acreage of each block in ha

Daily Water Depression (mm/day)	RB	CB	NB	DB	Total
20	2769	6489	937	81	10276
15	3032	6374	789	81	10276

(2) The total project requirement throughout irrigation season

The total project requirement throughout irrigation season (TQ) is calculated as follows.

The TQ is defined as the value that sum of requirements at each growing stage added to requirement at the puddling and transplanting stage. Requirements of each growing season can be determined as the maximum project requirement (calculated above) multiplied by seasonal factors and days.

Under the condition of seasonal factors given in Table 6, the TQ is calculated as follows: In Case 1 (20 mm/day), TQ=1455 mm, in Case 2 (15 mm/day), TQ=1633 mm.

The total requirements throughout irrigation season are estimated at 150 million m^3 for Case 1 (20 mm/day) and at 120 million m^3 for Case 2 (15 mm/day).

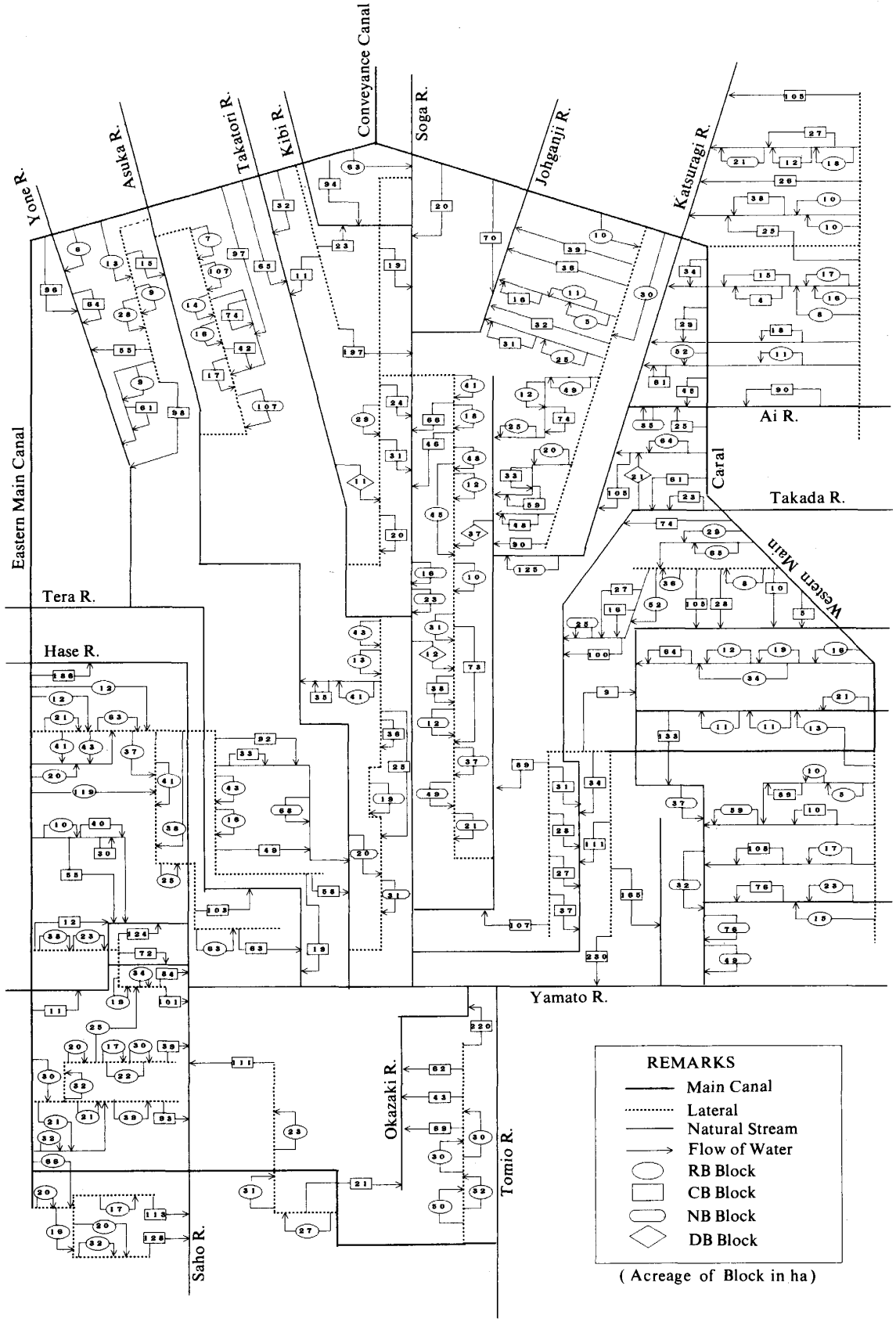

Fig. 3 A diagram of Irrigation System in the Yamato Plain Land Implovement District

Table 6. Seasonal factors and water requirement in volume

Period	Days	Seasonal Factor	Water Requirement in Volume ($\times 10^4 m^3$)	
			20mm/day	15mm/day
6/10~6/17	8	0.56	796.2	624.6
6/18~6/27	10	0.56	995.3	780.8
6/28~7/7	10	0.59	1048.6	822.6
7/8 ~7/17	10	0.63	1119.7	878.4
7/18~7/27	10	0.70	1244.1	976.0
7/28~8/6	10	0.77	1368.5	1073.6
8/7 ~8/16	10	0.92	1635.1	1282.7
8/17~8/26	10	1.00	1777.3	1394.2
8/27~9/5	10	0.81	1439.6	1129.3
9/6 ~9/15	10	0.64	1137.5	892.3
9/16~9/25	10	0.53	942.0	738.9
9/26~9/30	5	0.47	417.7	327.6
	Total		13921.6	10921.0

VI. Summary

TKP is one of the most successful projects for large scale integrated development of water resources in Japan. YPD is satisfied with enough diverted water from the Yoshino Bunsui. The amounts of water supplied by both the Yoshino Bunsui and local water sources such as natural streams, ponds and ground water, seem to become stable and rather excessive due to substantial transfer of paddy fields and incentives of saving water by YPD today.

By the analysis of the water requirement, it is revealed that the rehabilitation of the Yoshino Bunsui irrigation system is one of the possible ways to meet the future demands of municipal water.

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