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Effective flood control through integrated and collaborative dam operation at three dams in the upper Nabari River

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ABSTRACT: Heavy rain with the 18th typhoon threatened the Nabari River Basin, Kansai region with causing inundation early in the morning on 8th October, 2009. The Nabari River is a tributary of the Yodo river basin which contains Osaka and Kyoto and runs through Nabari City which is a residential zone as commutable distance area from Osaka city. In the upper reach of the Nabari, there are three multi-purpose dams; Shorenji Dam, Hinachi Dam, and Murou Dam, which are operated by Kizugawa Integrated Dam Control and Management Office (KIDCMO), branch office of Japan Water Agency (JWA). Since it rained heavily in the downstream of the three dams, the regular operation by three dams complying with the given flood control regulation seemed not to be able to prevent Nabari City from inundation. Therefore, JWA and Ministry of Land, Infrastructure, Transport and Tourism (MLIT) conducted collaborative operation of the three dams to avoid the inundation in the city area.

In this case, flood control operation of three dams commenced in early stage before the inflow reached the defined flood discharge in consideration of the water level of the Nabari River, rainfall condition and capacity of the reservoirs. During the operation, discharge from the dams was changed timely and appropriately through the collaborative work of the three dams in order to maximize the effectiveness of all flood control capacities of the reservoirs according to the latest rainfall forecast technology and runoff analysis.

The use of improved rainfall forecast technology and runoff analysis model enabled the effective application of this flexible operation protocols. It is estimated that this operation has resulted in 1.5 m decrease of the water level at Nabari design control point, and prevented approximately 1200 households from inundation.

Considering the recent climate change, it is possible to have extreme rainfall more often. The proof of adaptability of this flexible operation is quite meaningful not only for flood damage mitigation in the downstream, but also for future prospects of flood control by dams.

1 INTRODUCTION

The River Bureau of Ministry of Land, Infrastructure, Transport and Tourism, Japan (MLIT) is in charge of flood management and mitigation. Particularly, 109 large scale river systems are directly managed by the Ministry. Japan Water Agency (JWA) is constructing dams, estuary barrages, facilities for lake and marsh development, and canals in seven major and legally designated river basins out of above 109 river systems. Also, it is operating, managing and reconstructing completed facilities. The mandate of JWA is based on the Water Resources Development Promotion Law and Japan Water Agency Law. The Yodo river is one of seven basins and covers Osaka and Kyoto cities.

October 13th, 2009, the typhoon 18th with heavy rain came closest to Kansai and Tokai area. Its rain ranged all over Japan and caused lots of casualties and damages. As of 15:00 on October 8, the Fire and Disaster Management Agency reported five people killed, 127 people injured, and 4328 houses damaged.

Early morning on October 8th, the heavy rain threatened Nabari city in Mie Prefecture with causing significant inundation. Nabari city locates in commutable area to Osaka and

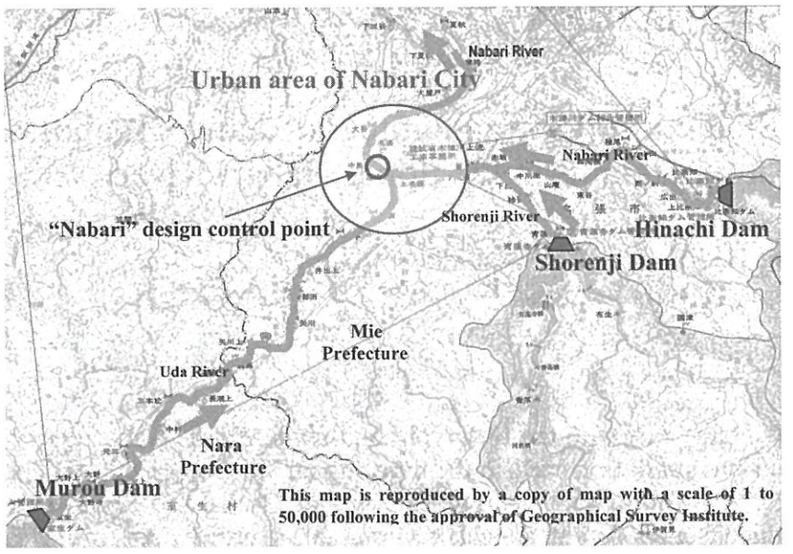

Figure 1. The location of three dams in the upper Nabari River.

Table 1. Specifications of three dams in the Nabari River upstream.

Shorenji Dam	Hinachi Dam	Murou Dam
【Dam Data】 Type: Concrete arch dam Dam height: 82.0 m Dam crest length: 275.0 m Catchment area: 100 km^2 Effective capacity: 23,800,000 m^3 Flood control capacity: 8,400,000 m^3 Start of management: July, 1970 【Purposes of dam】 1. Flood control 2. Maintenance of normal function of flow 3. Water supply 4. Agricultural water 5. Power generation	【Dam Data】 Type: Gravity concrete dam Dam height: 70.5 m Dam crest length: 355.0 m Catchment area: 75.5 km^2 Effective capacity: 18,400,000 m^3 Flood control capacity: 9,000,000 m^3 Start of management: April, 1999 【Purposes of dam】 1. Flood control 2. Maintenance of normal function of flow 3. Water supply 4. Power generation	【Dam Data】 Type: Gravity control dam Dam height: 63.5 m Dam crest length: 175.0 m Catchment area: 136 km^2 Effective capacity: 14,300,000 m^3 Flood control capacity: 7,750,000 m^3 Start of management: April, 1974 【Purposes of dam】 1. Flood control 2. Maintenance of normal function of flow 3. Water supply
		

has eighty thousand populations. The Nabari River which is a tributary of the Yodo river runs through the city center. Since it rained heavily, the regular flood control operation based on management rules by three dams; Shorenji Dam, Hinachi Dam, and Murou Dam in the upper Nabari River, managed by Kizugawa Integrated Dam Control and Management Office (KIDCMO), branch office of JWA, might not prevent inundation.

Therefore, KIDCMO and Yodogawa Integrated Dams Control Office (YIDCO), branch office of MLIT conducted the collaborative operation of the three dams to avoid inundation in the city area.

The integrated flood control operation of the three dams started before the volume of run-off reached the flood discharge; taking then water level in the Nabari River, rainfall intensity,

and the capacity of the three dams into considerations. During flood control operation, outflow discharge from the dams was under timely and appropriate control by the operations to make the most of storage capacities and collaborative operations of the three dams employing the latest rainfall forecast technology and runoff analysis.

The latest rainfall forecast technology and runoff analysis model enabled the effective flood control operation of the three dams. The effect of the operations was estimated to lower the water level in the Nabari River by 1.5 m and prevent inundation of approximately 1,200 households comparing with the case without the dams.

Considering the recent climate change, heavy rains are more likely to occur than before. The proof of the adaptability of flood control operation to reduce damages in the downstream means not only the prevention of the flood damage in the downstream, but also the future prospects for flood control for dams.

This report shows the state of implementation and effects regarding to flood control operation (three dam integrated operation)

The locations of the three dams in the Nabari River upstream are shown in Figure 1 and principal features in Table 1.

2 SUMMARY OF THE FLOOD CONTROL BY JWA

Incorporated administrative agencies are established and given objectives and missions by the national government to carry out "administrative tasks and projects, where implementation should ensure public benefits such as stable public life and social and economic activities." JWA is one of this type of agencies and mandated to construct and manage the facilities for water resource development such as dams for water supply and flood control, and canals in seven water systems (Tone River/Ara River/Toyo River/Kiso River/Yodo River/Yoshino River/Chikugo River) based on Japan Water Agency Law.

As for dams, JWA carries out flood control following the management rules of each dam based on Japan Water Agency Law. Each management rule has two types of operations; one is a regular operation that regulates outflow discharge from dams to cope with an expected large scale flood in the dam basins, and the other is a special operation that carries out the most suitable flood control considering the situation of the rain and the downstream rivers.

As for the special operation, the management rule doesn't have any rule regarding the outflow discharge from the dam, but when JWA carries out special operation, an instruction from the Integrated Dam Control and Management Office (MLIT) is necessary. This cooperative flood control operation of the three dams on this report was carried out following the instruction from YIDCO after KIDCMO and YIDCO thoroughly examined and adjusted.

3 FLOOD CONTROL OPERATION

3.1 *The day before the typhoon 18 hit Nabari*

From the afternoon on October 7, in order to prepare for the approach of the typhoon 18, KIDCMO inspected discharge facilities and warning facilities of dams and started forecasting the rainfall and the amount of inflow in each dam based on the typhoon course forecast.

With the increase of the amount of inflow to the dams, KIDCMO started contacting to the related institutions and patrolling the down stream river sequentially from 18:00 at Murou Dam, and from 20:30 at Shorenji Dam and Hinachi Dam. One hour later, each dam started discharging from spillways facilities.

When each dam started discharging from spillways facilities, the typhoon 18 was heading more easterly which meant it wouldn't rain heavily in the Nabari River basin according to the typhoon course forecast.

3.2 *Rise of the Nabari River water level*

A rain forecast changed significantly around 2:00 on October 8.The forecast showed that the water level in the Nabari River, in the downstream of the dams, would exceed flooding attention water level, and continue rising. Figure 2

For this reason, MLIT instructed KIDCMO to start operation to prevent the inundation in the city area by controlling the water level in the Nabari River. In order not to raise the water level in the Nabari River, three dams in the Nabari River upstream were required to reduce the outflow discharge to the downstream of the dam. In this case, the outflow discharge from the dam was carefully arranged because storage capacity for flood control would be filled up if heavy rain continued.

Although the speed of the typhoon was accelerated, still it was forecasted that heavy rain would continue. So it was necessary to adjust the outflow discharge based on the observed precipitation and changing forecast.

At 3:15, KIDCMO started special operation to keep the outflow discharge (Shorenji Dam 250 m^3/s, Murou Dam 250 m^3/s, Hinachi Dam 150 m^3/s) less than the outflow discharge during regular operation that means increase the outflow discharge of Shorenji Dam 450 m^3/s, Murou Dam 300 m^3/s, Hinachi Dam 300 m^3/s in consultation with the Nabari City. Figure 3

Following operations were implemented by KIDCMO under the instructions from MLIT after their close consultation.

Prediction of water level at Nabari

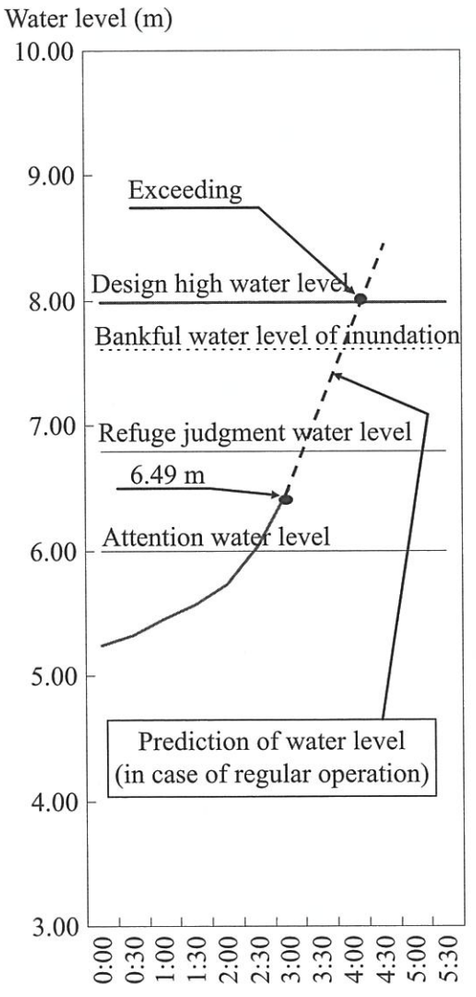

Figure 2. Prediction and judgment at 3:00.

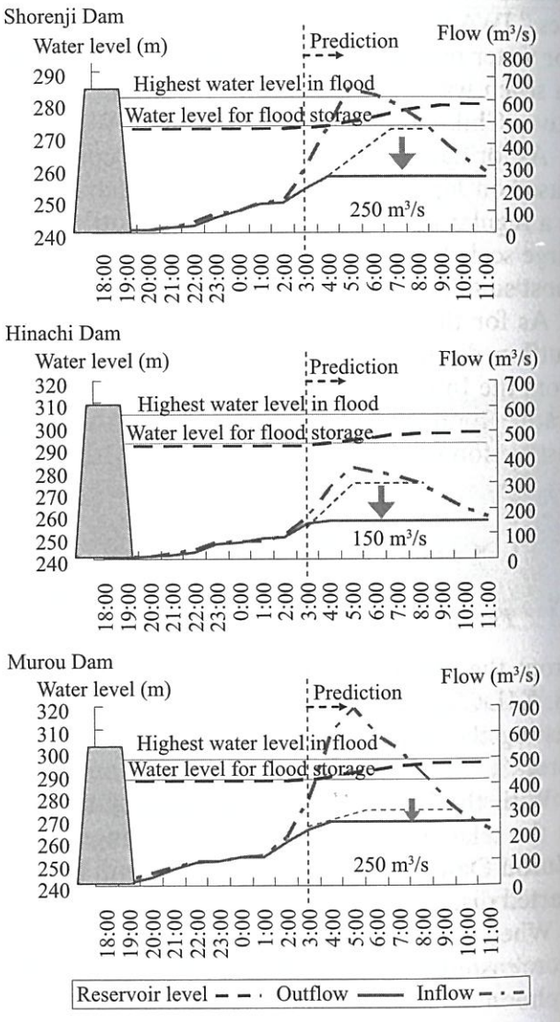

Figure 3. A prediction and the dam operation at 3:00.

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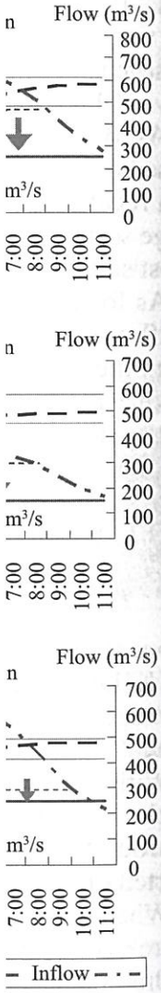

ı operation at 3:00.

3.3 *Integrated and collaborative dam operation at the three dams in the Nabari River upstream*

At 3:40, Shorenji Dam's storage capacity for flood control might possibly be filled up if Shorenji Dam continued to store up the water without increasing the outflow discharge in this heavy rain. On the other hand, the water level in the Nabari River continued rising, and it was forecasted that if this continued, the water level in the Nabari River would reach the bankful water level of inundation and bring an inundation damage to the city area. For this reason, it was difficult to increase the outflow discharge from the dams although inflows to the dams largely increased. Figure 4

At 4:00, the water level in the Nabari River was expected to rise not too quickly due to the gradual increase of outflow discharge from Shorenji from current 250 m³/s to 450 m³/s. After considering the rainfall forecast, the water level prediction in the Nabari River, the flood control capacity and the inflow prediction of the three dams, it was decided that the outflow discharge from Hinachi Dam would be reduced by 100 m³/s to 50 m³/s, instead of increasing the amount of discharge from Shorenji gradually. Figure 5

3.4 *Decline of water level in the Nabari River*

At 4:40, since the rainfall in Murou Dam basin was less than forecasted, it was decided to make the water level in the Nabari River lower by decreasing the outflow discharge from

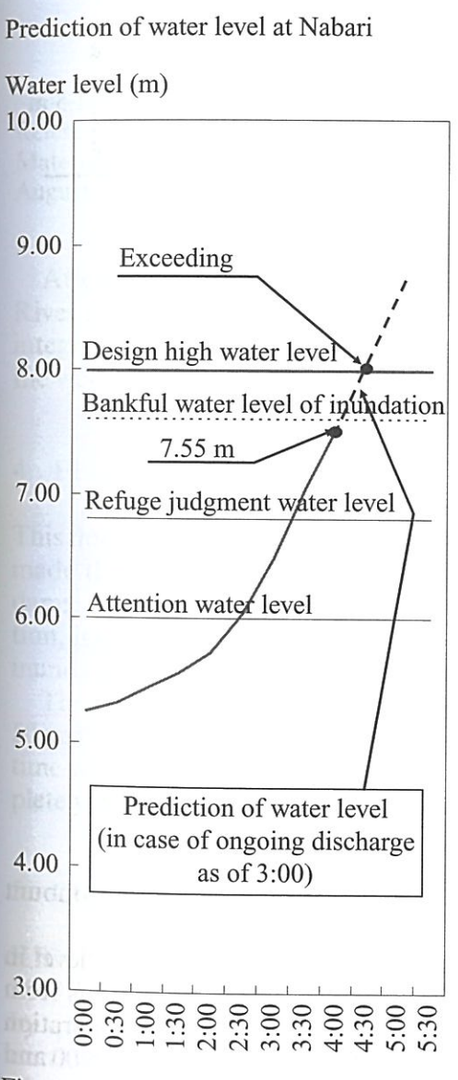

Figure 4. Prediction and judgment at 4:00.

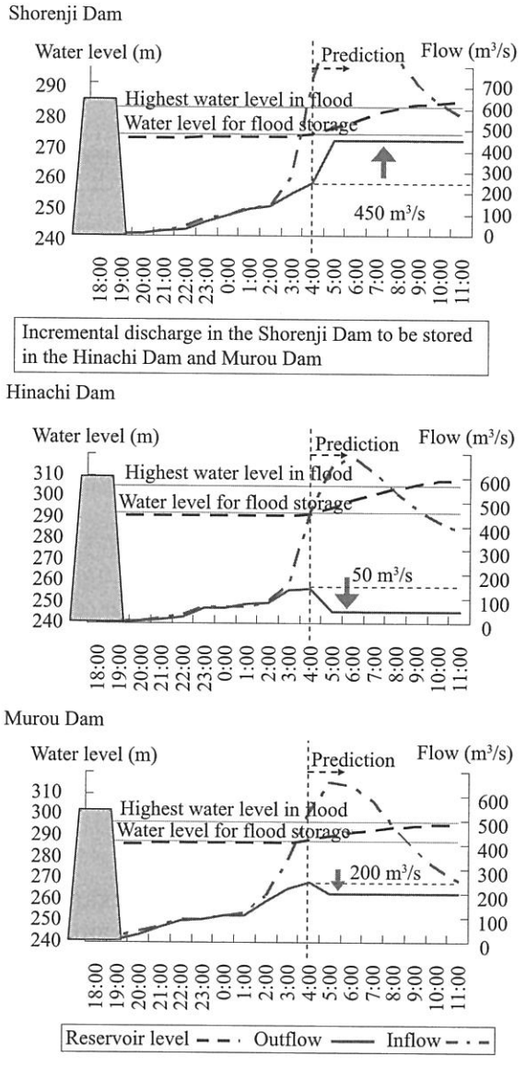

Figure 5. A prediction and the dam operation at 4:00.

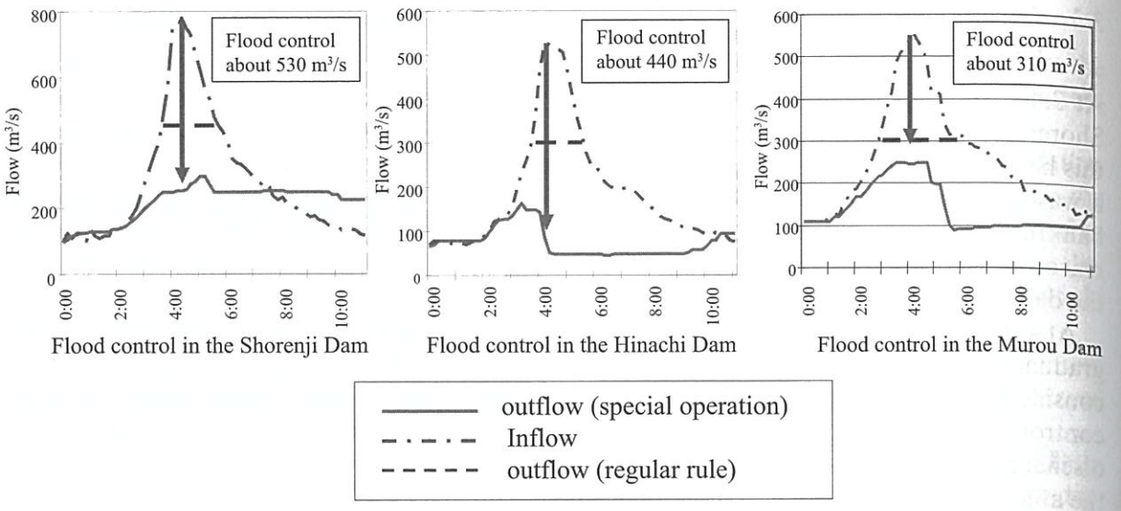

Figure 6. The flood control operation of three dams.

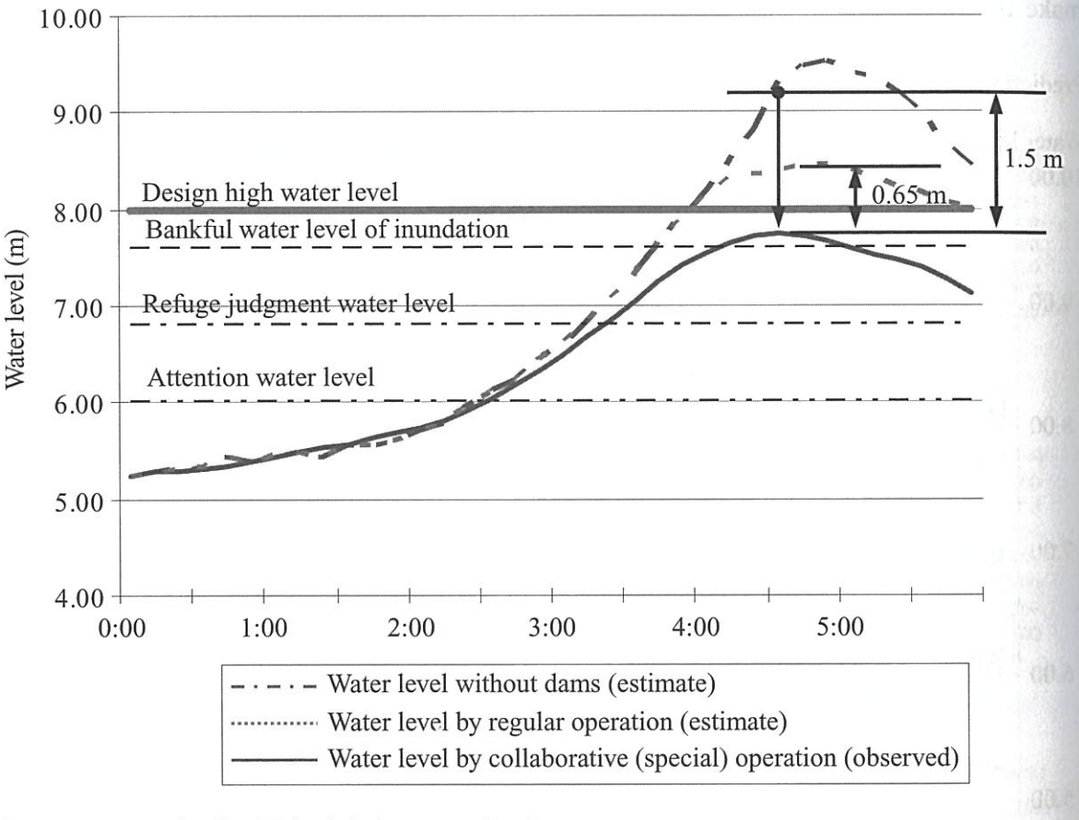

Figure 7. Water level at Nabari design control point.

Murou Dam to 200 m³/s by the smart examination based on observed data and the amount of inflow, because there is no time to examine with considering the rainfall forecast.

As a result of repeated examinations and operations with forecasting the water level in the Nabari River and so on, the outflow discharges were finally decreased to 250 m³/s from Shorenji Dam, 100 m³/s from Murou Dam, and 50 m³/s from Hinachi Dam. This operation made the water level at Nabari design control point lower than bankful water level at 5:00 and lower than refugee judgment water level at 6:20.

Table 2. Comparison with the Isewan Typhoon in 1959.

Details			Typhoon No.18, 2009	Isewan Typhoon, 1959
Scale	Period		Sep 29 (21:00) to Oct 9 (15:00)	Sep 21 (21:00) to 27 (21:00)
	Lowest pressure		910 hPa	895 hPa
	Maximum wind		55 m/s	75 m/s
At landfall	Central pressure		955 to 960 hPa	925 hPa
	Maximum wind		40 m/s	50 m/s
	Radius storm wind		220 km (SW), 170 km (NW)	250 km
Rainfall in the upper Nabari	1-hour rainfall		65 mm	58 mm
	3-hour rainfall		145 mm	137 mm
	Cumulative rainfall		315 mm	393 mm
Nabari city Rainfall	1-hour rainfall		41 mm	43 mm
	Cumulative rainfall		239 mm	342 mm
Damage	Death		–	11
	Missing		–	1
	Swept houses		1	102
	Demolished houses			180
	Partially destroyed		–	525
	Inundated floor level	above	1	1434
	Inundated floor level	below	27	848

Reference: Meteorological Agency, History of the Kizu River (1980), Interviews by Nabari City Material about flood in the Yodo River and the Yamato River (liaison council of flood forcasting, August 1960).

Afterwards, the flood control operation was continued till the water level in the Nabari River became lower than warning water level, and flood control operation was shifted to the integrated control operation to decrease the water level in each three dam in order not to raise the water level in the Nabari River. Figure 6

4 FLOOD CONTROL EFFECT

This flood control regarding special operation by the three dams in the Nabari River upstream made the water level for approximately 1.5 m lower than the water level without the three dams, and for approximately 0.6 m lower than the regular operation. With this special operation, it is assumed that approximately 1200 households in Nabari City area were saved from inundation damage. Figure 7

There is a comparison between typhoon 18 and Isewan typhoon that hit the Nabari City 50 years ago in the damages in the Nabari City area. Despite the rainfall in three hours this time was equal to that of Isewan typhoon, the damages the Nabari City suffered were completely different. Table 2

5 CONCLUSION

KIDCMO received a letter of appreciation from the mayor of Nabari City on October 20, 2009 due to the "Great contribution for reduction of the flood damage in the Nabari River by quick and appropriate flood control operation". In fact, during the special operation, outflow discharge was arranged ten times in only 2 hours by getting and considering data observed in every ten minutes.

In addition, this flood control operation was highly evaluated by Japan Society of Civil Engineers (JSCE) because of its crisis control ability and operating performance. KIDCMO and YIDCO won the Outstanding Civil Engineering Achievement Award of 2009 from JSCE on May 28, 2010. It was the first splendid achievement that the operation of the dam won the JSCE Award.

This special operation was able to be carried out by understanding the capacity of flow in the river in downstream of the dams, and using the outflow forecast system based on the observed rainfall and forecasted rainfall. KIDCMO will improve the outflow prediction system, in order to aim the higher stage of flood control operation in the future.