6. Prevention of Disasters Related to Rivers

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PREVENTION OF DISASTERS RELATED TO RIVERS

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ABSTRACT

The author describes various problems on the disasters related to rivers in Japan from physical and socioeconomical viewpoints. The following contents are included: the importance of flood disaster prevention in national development, characteristics of flood disaster in relation to topographical and geological conditions, major problems on flood disasters arising from socioeconomic development, especially, on the characteristic change of flood runoff resulted from human activities, and historical development of measures and technology for flood disaster prevention.

The author stresses the necessity of synthetic measures so as to meet changing features of flood disaster resulted from basin development.

1. THE IMPORTANCE OF FLOOD DISASTER PREVENTION IN NATIONAL DEVELOPMENT

Disasters occur in the relation between nature and mankind. Disasters related to rivers should therefore be examined synthetically not only from the viewpoint of anomalous natural phenomena and conditions but also from socioeconomic aspects such as land use, urbanization, a way of living etc..

Various aspects of disasters related to rivers and their countermeasures are therefore described in this chapter focusing on some cases in our country. The renge of problems treated here is mainly limited to flood disaster to avoid duplication with other related chapters, therefore, the descriptions of meteorological aspects of heavy rainfall, slope failure and sediment runoff and storm surge are only briefly mentioned.

Japan has frequently suffered from enormous flood disasters owing to her natural geographical conditions and intensive socioeconomic activities in the limited space avilable.

Average annual flood losses in Japan during the 35 years from 1946 to 1980 were counted as 946 dead and missing persons, 3,552 wounded persons, and the average annual cost of damage at the price level of 1980 amounted to ¥540.1 billion (US$2.16 billion), about 0.36% of the national income. On the other hand, the average annual expenditure of investment for flood control works and disaster rehabilitation amounted to ¥594.8 billion

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(US$2.37 billion) in the same period.

Flood losses and damage in the countries of the ESCAP region are shown in Table 1 and 2. Thus, many countries have suffered from flood disasters every year and it is one of the major factors preventing socioeconomic development in these countries. Therefore, continuous efforts to cope with flood disaster are indispensable to ensure people's welfare and to establish socioeconomic bases for development. To this end, we must have a full understanding of flood disaster problems not only from scientific and technological but also from the socioeconomic point of view and work out effective countermeasures suited to the specific conditions in each country.

2. RAINFALL CHARACTERISTICS CAUSING FLOOD HAZARDS

In Japan, most flood hazards are caused by heavy rainfalls brought from bai-u fronts in June and July, and typhoons in summer and fall seasons. Moreover, we have frequently flood hazards caused by thunderstorms in local areas and by snowmelting in areas on the Japan Sea coast side.

Rainfall intensity and its time and spacial distributions seriousely affect the scale and features of flood hazards. In general, heavy rainfalls are brought from bai-u fronts or typhoons and often from frontal activities joined with a typhoon, so they have vast spatial distribution, accordingly, they cause large-scale flood hazards and disasters over wide areas. The amount of rainfall brought from bai-u fronts and typhoons except for the northeastern part of the country occupies 40-50% of the average annual precipitation, and a typhoon of mean scale brings rainfall of about 25 billion m^3 over vast areas, whereas a large scale typhoon brings heavy rainfall to the amount of 50 billion m^3 or more.

Maximum daily rainfalls observed in the past by the Meteorological Agency are shown in Fig.1. Also, local heavy rainfalls brought from meso and small scale disturbances cause flood hazards in small watersheds or urban areas frequently. In these cases, short period rainfall intensity for one hour or even 10 minutes is very significant for the occurrence and features of flood hazards. The maximum rainfalls recorded over one hour and over 10 minutes are 187mm and 49mm respectively.

Meanwhile, the threshold amount of rainfall that causes flood hazards in a region is generally proportional to the amount of maximum daily rainfall recorded in that region. This means that there exists regional resistivity against flood hazards. Although the occurrence of flood hazards depends upon the the rainfall pattern, some kinds of flood disasters would happen in the most part of the country if the amount of daily rainfall exceeds 150mm. However, in the southwestern part of Japan, flood disasters don't happen generally until the daily rainfall amounts to 300 mm. On the contrary, in the northeastern part of the country, flood disasters occur frequently even when the daily amount of rainfall does not exceed 150mm.

In spring time, high water levels caused by the melting of snow last during 2 to 4 weeks in the rivers of the Japan Sea coast side, but in general, they do not cause serious flood hazards except in the event of heavy rain and rapid rise of temperature occur together.

3. PATTERN OF FLOOD HAZARDS FOR THE DIFFERENT TOPOGRAPHICAL AND GEOLOGICAL CONDITIONS

(1) Flood hazards in headwaters areas

Flood hazards have different features according to topographical and geological conditions. On the steep slopes in mountainous and hilly lands, erosion of ground due to surface flow, slope failure and landslide due to excessive groundwater occur and they produce enormous amount of sediment.

The violent mud avalanche and mud flow wash away all the things existing in their courses and bury many houses situated at the foot of mountain.

The people living in a mountainous terrain have suffered from this pattern of flood disasters since old time. Following four examples illustrate as the typical disaster. (see Table 3)

1) Flood disaster at Ashiwada Village in Yamanashi Prefecture due to typhoon 6626(Ida) in Sept. 1966.
2) Flood disaster at Shirakawa Town in Gifu Prefecture due to typhoon 6807 (Polly) in Aug. 1968.
3) Flood disaster at Shōdojima island in Hyōgo Prefecture due to typhoon 7617(Fran) in Sept. 1976.

Many parts of our country are covered by volcanic materials. These areas have special hydrological characteristics such as high infiltration and water holding capacity which act to eliminate flood runoff. However, these areas are very vulnerable to erosion owing to their geological and soil mechanical natures and cause various hazards such as slope failure, channel erosion, mud flow etc.. Sirasu region in sourthern Kyūshū covered by the thick sediment layer of volcanic ashes and pyroclastic materials is the one of typical area suffering from such hazards.

(2) Flood hazards on valley plains and alluvial fans

On valley plains and alluvial fans, sediment load discharged from mountainous areas is deposited in the river channels and silts up river beds. At the same time, the vast amount of drifting woods produced by many landslides and slope failures in the upstrem areas is caught by bridges or accumulates on the river channels. As the result, the flood tends to flow disorderly and to give harmful effects to the river banks. Further, if the flood breaks a river bank, the flooded area is seriousely damaged by the violent mud flow. In Japan, many rivers on valley plains and alluvial fans form higher river bed levels than the adjacent ground levels (such river is called "ceiling river", therefore, these rivers are potentially dangerous for causing disasterous floodings. Typical flood disasters of this pattern in our country are illustrated in the following three cases.

1) Flood disaster in the Kano River basin in Shizuoka Prefecture due to typhoon5822 (Ida, so called Kanogawa Typhoon) in Sept. 1958.
2) Flood disaster in the river basins of Nagasaki City in Nagasaki Prefecture due to bai-u front storm in July 1982.
3) Flood disaster in the river basins in the western part of Shimane Prefecture due to bai-u front storm in July 1983.

(3) Flood hazards on alluvial plains

Flood hazards on alluvial plains are mainly characterized by the wide spread flooding and the long-term inundation. Generally, the duration of flooding in the lower reaches of a river is longer than that in the upper reaches owing to the flattening of the flood-wave as it flows down a river course.(see Fig.3) Therefore, harmful effects due to flooding and inundation in the downstream areas are larger than that in the upstream areas.

In our country, the large rivers have catchment areas of no more than 18,000 Km^2, and their durations of flooding and inundation are usually within several days. The alluvial plain occupies only 13% of the national land on which the greater part of agricultural and industrial productions is carried out and many large cities are also located. In order to protect these areas from flooding and inundation, levees and drainage facilities have been constructed along almost all of the rivers. As the result, the flood runoff has come concentrated rapidly in the river course as well as the flood stage heightened seriousely . Accordingly, in the event of levee broken by flood flow, there exists the possibility of furthering flood damage due to the increased energy of flooding water and the prolonged duration of inundation in the protected lowland.

In recent years, large scale flood disasters due to levee breaching have remarkably diminished owing to the advancement of river improvement works and the construction of flood control reserviors.

Typical examples of this type of disaster are shown in the following four cases.

1) Flood disaster in the Tone River basin due to typhoon 4709(Kathleen) in Sept. 1947.
2) Flood disaster in the Chikugo River basin due to bai-u front storm in July 1953.
3) Flood disaster in the Ishikari River basin due to typhoon 7506(Rita) in Aug. 1975.
4) Flood disaster in the Nagara River basin due to typhoon 7617(Fran) in Sept. 1976.

(4) Flood hazards in coastal areas caused by storm surge

We have often suffered from storm surges caused by typhoons in coastal areas. In the event of occurrence of storm surge together with high tide and flood runoff from a river, the high water level of the river is further heightened and the danger of flooding in the lower reaches of the river is seriousely increased. Coastal areas are usually low-lying lands and on which many urban functions such as industrial, transportational facilities, energy supply systems etc., and dwellings and buildings are densely located. Furthermore, ground levels in the some parts of these areas are under mean sea level due to land subsidence resulted from excessive withdrawal of groundwater. Therefore, these areas have been protected by strong high levees and tide gates, but they still have very vulnerable nature to storm surge.

The flooding caused by the storm surge due to typhoon 5915(Vera, so called Isewan Typhoon) in Sept. 1959 gave the severest damage on the coastal area along the Ise Bay.

4. CHARACTERISTICS OF FLOOD RUNOFF AND THEIR CHANGES

The important characteristic of flood runoff from the viewpoint of flood control is the shape of the time distribution of flood discharge or stage, namely flood hydrograph which includes the magnitude of peak flood discharge or stage, lag-time and duration of flood. Lag-time means the time interval between the time of occurrence of maximum rainfall intensity in a drainage area and that of peak flood discharge at a observed points.

Under the same hydrological conditions, the specific peak flood discharge is inversely proportional to the magnitude of a drainage area, and the lag-time is proportional to it. Therefore, violent and rapid flood runoff with a sharp crested hydrograph, namely flush flood occurs in the upper reaches of a river with small drainage areas. On the contrary, flood runoff with a gentle crested hydrograph and long duration occurs in the lower reaches of a river with large drainage areas.(see Table 4 and Fig,3)

In other words, the characteristics of flood runoff are seriousely affected by the change of hydrological processes in a drainage area such as infiltration, retention, storage, surface runoff and groundwater runoff.

In recent years, many hydrological observations and investigations have been carried out in various watersheds for the purposes of river improvement works, flood forecasting, flood control and drainage works. In addition, various mathematical models for simulation of river discharge from rainfall data have been developed. However, human influence to the hydrological conditions is apt to be accelerated and enlarged in the future and to act in the direction of hastening lag-time and increasing peak flood discharge. Researches on the estimation of human influence on hydrological regime have been carried out by means of experimental basins in forests and urbanizing areas, but the effective methods to estimate the future change of hydrological regime corresponding to the development of a river basin have not yet been fully established. Therefore, the estimation of flood runoff under changing hydrological conditions of a drainage area by human activities become a major problem in hydrological research. (see Fig.4 a,b,c,d)

5.SOME MAJOR PROBLEMS ON FLOOD DISASTER ARISING FROM SOCIOECONOMIC DEVELOPMENT

Flood losses have a tendency to increase their number and damage cost according to socioeconomic development. This means that the problem of flood disaster must be discussed from the viewpoint of mutual interactions between the physical aspects of flood hazards and socioeconomic ones. Here, some major problems on flood disaster are presented from socio-economic viewpoint.

(1) Rising of damage potential corresponding to socioeconomic development

The figures of population and total cost of assets within the areas protected from flooding in our country in 1960, '70 and '85 are shown in Table 5. They represent rapid increase of factors subject to flooding, and this fact necessitates the continuous strengthening of countermeasures for prevention of flood disaster corresponding to socioeconomic development.

(2) Increasing flood disasters and changing their patterns due to urbanization

In Japan, the concentration of population in large cities has been seriousely promoted by the economical development since about 1955. In addition, the urban developments have sprawled outward the cities, where the original land uses were farm and forest in the hilly land and paddy field in the alluvial plain. As the result, hydrological conditions in the newly developed areas have been seriously altered by the improvement of original land forms, deforestation, house building , road pavement, drainage works and so on. In these urbanizing areas, inhabitants frequently suffer from flood hazards caused by increased flood runoff, slope failure and sediment runoff. Furthermore, such increased flood runoffs give hazardous effect to the cities situated in the downstream areas, and they compel the cities to further strengthen the countermeasures for flood protection such as enlargement of river courses, construction of diversion channels and heightening levees. However, the excution of these countermeasures is practically very difficult for highly developed cities.(see Table 6)

(3) Encroachment of human activities to the areas vulnerable to flood hazards

Recently, owing to the development of transportation, many people go camping, climbing and sight-seeing in the mountainous country. On the other hand, increasing demands for land to make houses and factories force the people to use the areas more vulnerable to flood hazards because they are generally of low cost and easy to obtain. Such tendencies increase the opportunity of suffering from flood hazards and flood losses.

(4) Weakening of flood fighting activities in local areas due to the shifting of population to urban areas

The reduction of young and adult people living in local areas due to urbanization is seriously preventing effective activities for protection, evacuation and relief from flood hazards in the areas.

6. PROTETIVE MEASURES AGAINST FLOOD DISASTER

There are two ways to perform protective measures against flood disaster. The one is the structural approach such as river improvement works, sabo works, flood control by dams, afforestation, etc., while the other is the non-structural one which includes flood forecasting, regulating of land uses of flood prone areas, emergency evacuation, flood fighting, relief activities , etc.. These measures have been developed since old times under various conditions and circumstances, such as the pattern of flood disaster, socioeconomic demand, technical level and financial restriction at the time and the region concerned.

The knowledge and experience concerning flood protection obtained through historical process are very valuable and they should be paid full attention even at the present when mostly common measures are excuted by the application of modern science and technology. Besides, it is very important to have an individual and community preparedness for flood disaster prevention as well as the systematic implementation of flood protection measures by governmental and local autonomous bases. Therefore, public enlightenment and dissemination of the knowledge on the preparedness for flood disaster prevention, and public training of emergency activities and flood fighting are indispensable.

In this section,the historical outline of technical and administrative development of flood protection measures with some typical examples and major problems to be solved in our country are described.

(1) Before the Meiji Restoration

In this period, the flood protection techniques had been developed mainly from the standpoints of developing paddy field and inland navigation as well as securing irrigation systems from flood hazard. The saying "The one who controls water will govern the state" brought from an old Chinese proverb was the one used by all governers in those days. During the period of the civil wars in the 16th century, many lords developed and implemented various flood protection methods and techniques suited to the regional characteristics of floods and conditions aiming at economic development and strengthening their territories by the increasing of rice production and the elimination of flood damage.

For instance, Shingen Takeda who was an excellent lord of Kainokuni (at present Yamanashi Prefecture) constructed a skilful flood protection works at the confluence of Kamanashi River and its tributary, Midai River, where flood disasters had frequently occured on the downstream area from the confluence before the works owing to swift and violent running flood flows with enormous amount of sediment load. He made a diversion channel of the Midai River by ingenious utilization of the available topographical features and solid open levees and spur dikes along the left bank of the Kamanashi River to diminish flood flow energy. As the result, he succesfully eliminated flood disaster in that area. (see Fig.5)

In the Edo era (1600 to 1868), The Tokugawa Shogunate ruled the whole country and promoted the development of paddy field as well as flood protection works in major rivers. For instance, the improvement works of the Tone River initiated from the end of the 16th century for the purpose of eliminating flood disaster, securing of a stable food base and development of inland navigation for Edo City (at present Tokyo) which was the base of the Tokugawa Shogunate. In this works, the Tone River which originally flowed on the low-lying land in the eastern part of Saitama Prefecture and Tokyo Metropolis at present and into Tokyo Bay was changed its course at Sekiyado to meet the Kinu River which flows eastward into the Pacific Ocean. Owing to this works, the development of paddy field in the low-lying land was remarkably promoted by skilful utilization of the former courses of the Tone River as irrigation and drainage channels.(see Fig.6)

Three rivers, Kiso, Nagara and Ibi, flowed together in their lower reaches into Ise Bay, and had frequently caused flood disasters in the low-lying land of these downstream areas. The inhabitants in the areas had struggled against flood disasters by making circular levees surrounding their communities and cultivated lands, by building their houses on mounds with stone walls upper the highest flood water level and by keeping small boats for evacuation and relief. Besides, the Tokugawa Shogunate endeavoured to make levees by which the confluent river course in the lower reaches was separated into each of the three rivers in order to regulate disordered flood flows and eliminate flood disaster in the areas.(see Fig.7)

Thus, many flood protection works which were carried out in this period had played a significant role in setting up the socioeconomic bases to introduce modern civilization after the Meiji Restoration in 1868.

(2) From the Meiji Era to World War II

Japan has positively tried to modernize her social and economic systems by introducing Western civilization since the Meiji Restoration. As to the flood protection techniques, the Japanese government promoted modernization of them by inviting European river engineers to introduce modern scientific and technological methods on flood protection. Although the main emphasis was placed on the improvement works of river courses for irrigation and inland navigation at an early stage, river improvement works for flood protection of major rivers were carried out uniformly and continuously one after another by the government as well as local governments since the River Law was commenced in 1896 after frequent occurrence of flood disasters in 1880's.

The main objectives of river improvement works were prevention of flooding and discharging of river flood flow into sea as quickly as possible. For this purpose, cutoffs and diversion channels, levees, revetments and spurs were constructed in many rivers through the country.(see Fig.8)

These river improvement works were planned and designed based upon the past maximum flood discharge and stage in each river. On the other hand, in headwaters areas, sabo works were carried out in parallel with river improvement works in order to control erosion and sediment runoff and to prevent silting up of the downstream river beds.

After enactment of the Sabo Law and the Forest Law in 1897, the government and local governments positively and systematically carried out various measures such as afforestation and setting up flood protection forests in addition to sabo works to prevent devastation of mountain areas and to mitigate violent flood runoff as well as sediment runoff from headwaters areas.

By the begining of 1930's, the advancement of modernization in our country led to increasing water demands for domestic and industrial uses and electric power generation in addition to conventional agricultural water use, and the need for securing further safty against flood disaster in the developed areas. To meet this situation, the so-called "River flow Control Project" which aimed at the control of river flow by multi-purpose dams was initiated in 1937. However, this project was interrupted by the lack of funds and materials during World War II.

(3) After World War II

Immediately after World War II, Japan had to utilize her domestic resources in the most effective way for the reconstruction of the devastated land and to restore food and energy supplies. Besides, in the period of 15 years after the war, large scale flood disasters caused by typhoons and bai-u front storms occured frequently and burdened to the exhausted economy.

Taking account of such needs and circumstances mentioned above, the so-called "Integrated River Development Projects" centering on the construction of multi-purpose dams and municipal water supplies started in 1951 following the developmental strategy of TVA in the U.S.A.. At the same time, river improvement works, sabo works and forest conservation works have been strongly promoted.

In the period of these years, hydrological observation networks such as precipitation, stage and discharge have been extended throughout the country and many hydrological investigations and researches have been conducted. As the result, technology for flood control and planning method for river improvement works has been remarkably advanced.

However, corresponding to the rapid socioeconomic development in our country, various problems relating to flood disaster prevention and water uses have appeared as follows.

1) Rising of damage potential due to development
2) Increase of flood runoff and peak flood discharge due to land use changes, urbanization and improvement of river courses

3) Intensification of flooding and inundation in urbanizing areas and harmful effects of urban development to the downstream areas.
4) Increasing needs for water resources development and management corresponding to rising water demands.
5) Increasing danger of storm surge in low-lying coastal areas of large cities due to land subsidence caused by excessive withdrawal of groundwater.
6) Deterioration of river water quality.
7) Increasing needs for rivers in relation to recreational and environmental aspects.

With regard to these problems, the following measures have been performed.

1) Leveling up the probability exceedence on design flood, which is a fundamental basis for a flood control project, to the extent of 100 to 200 years according to the importance of the river to ensure safty against flooding. (see Table 7)
2) Promoting construction of multi-purpose dams and retarding basins to control flood flows as well as to ensure water supply against increasing water demands. (see Table 8)
3) Synthetic management of dams existing in the basin to ensure effective flood control and water supply.
4) Ensuring the implementation of various flood control measures in the urban development areas, such as river improvement works in small watersheds, setting up many small retarding basins,various works to increase the storage of rain water in underground soil layers, for examples, water pervious pavement of sidewalk, storage boxes to infiltrate water in the drainage system and so on.
5) Strengthening the proof functions against storm surge in major cities such as levees, tide-gates and drainage facilities, as well as regulating withdrawal of groundwater to prevent land subsidence.
6) Measuring water quality in public waters by setting up monitoring systems, as well as making attractive areas and recreational facilities within river courses in cities.

However, it is very difficult economically and practically to enlarge river courses and to set up diversion channels for the purpose of flood control in the highly urbanized areas, and also recently, many difficulties on the construction of dam have appeared owing to the limit of effective dam site and opposition of inhabitants. Such circumstances have come to compel us to examine the comprehensive flood control measures which include such ways of land uses and urban development as to eliminate flood runoff throughout the basin thereafter.

Fig. 1 Maximum daily rainfall in Japan

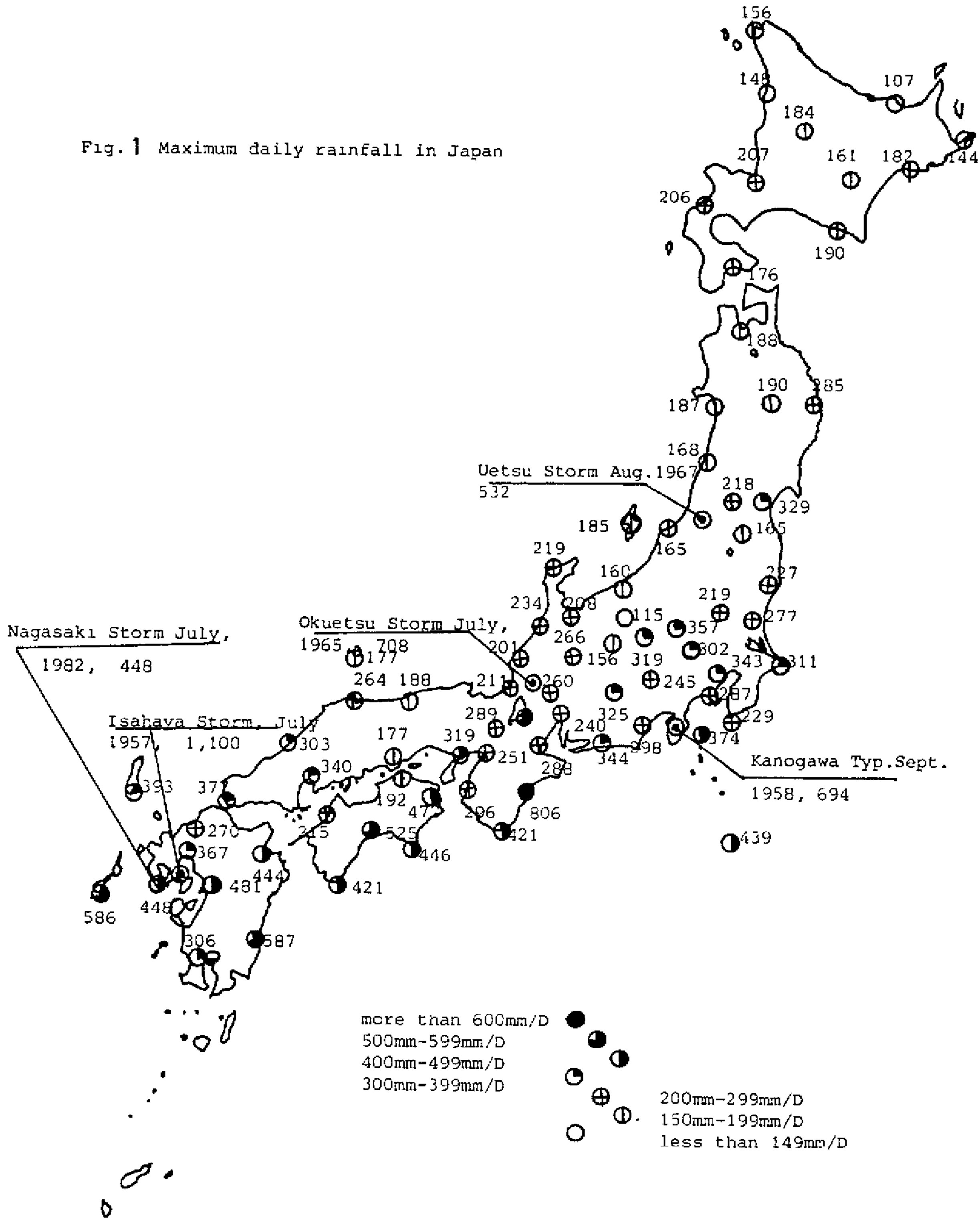


Fig.- 2 Main Rives in Japan

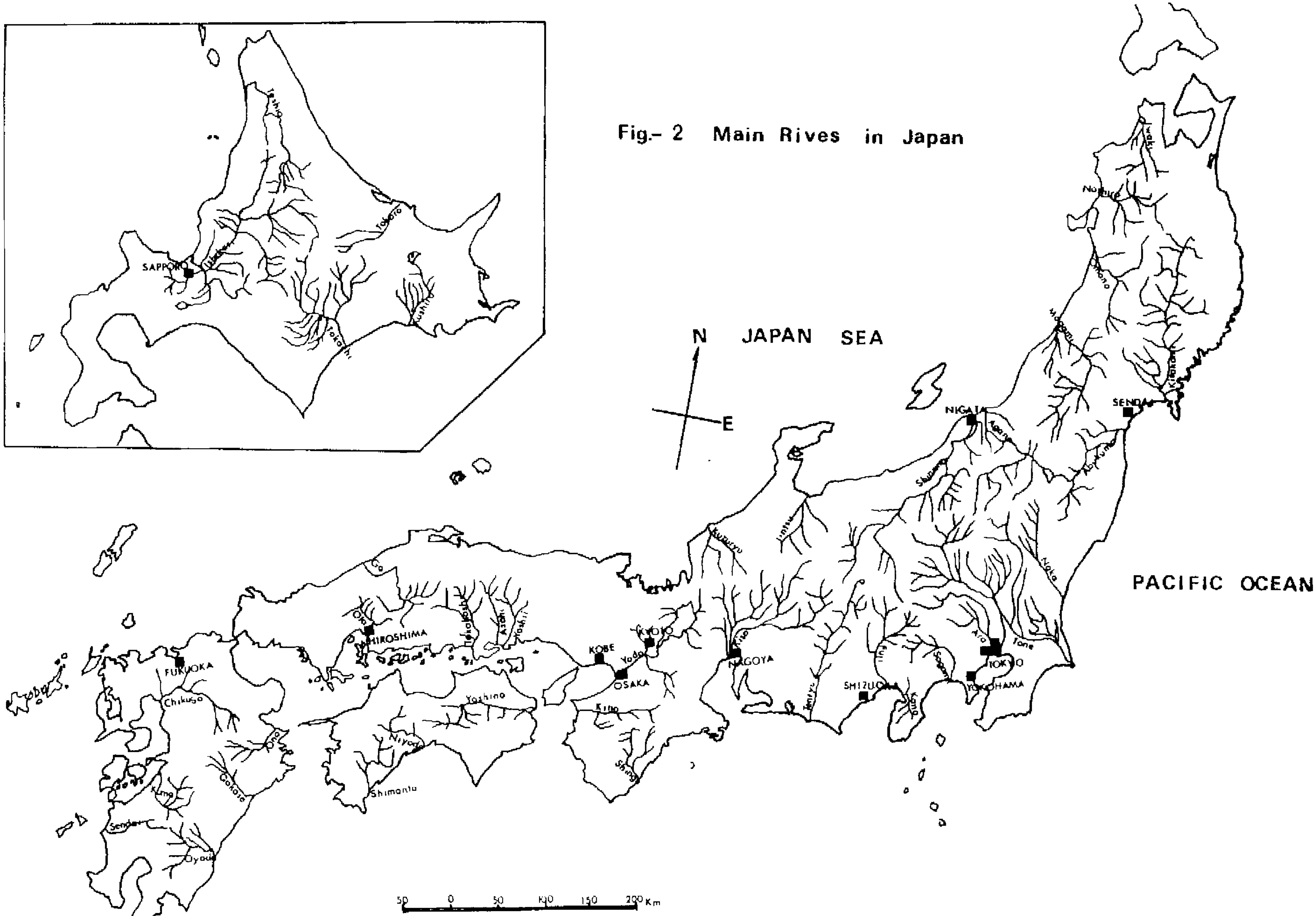


Fig.- 3 Propagation of Flood Wave and Its Change

(An Example: Flood of Ishikari River Aug. 1975)

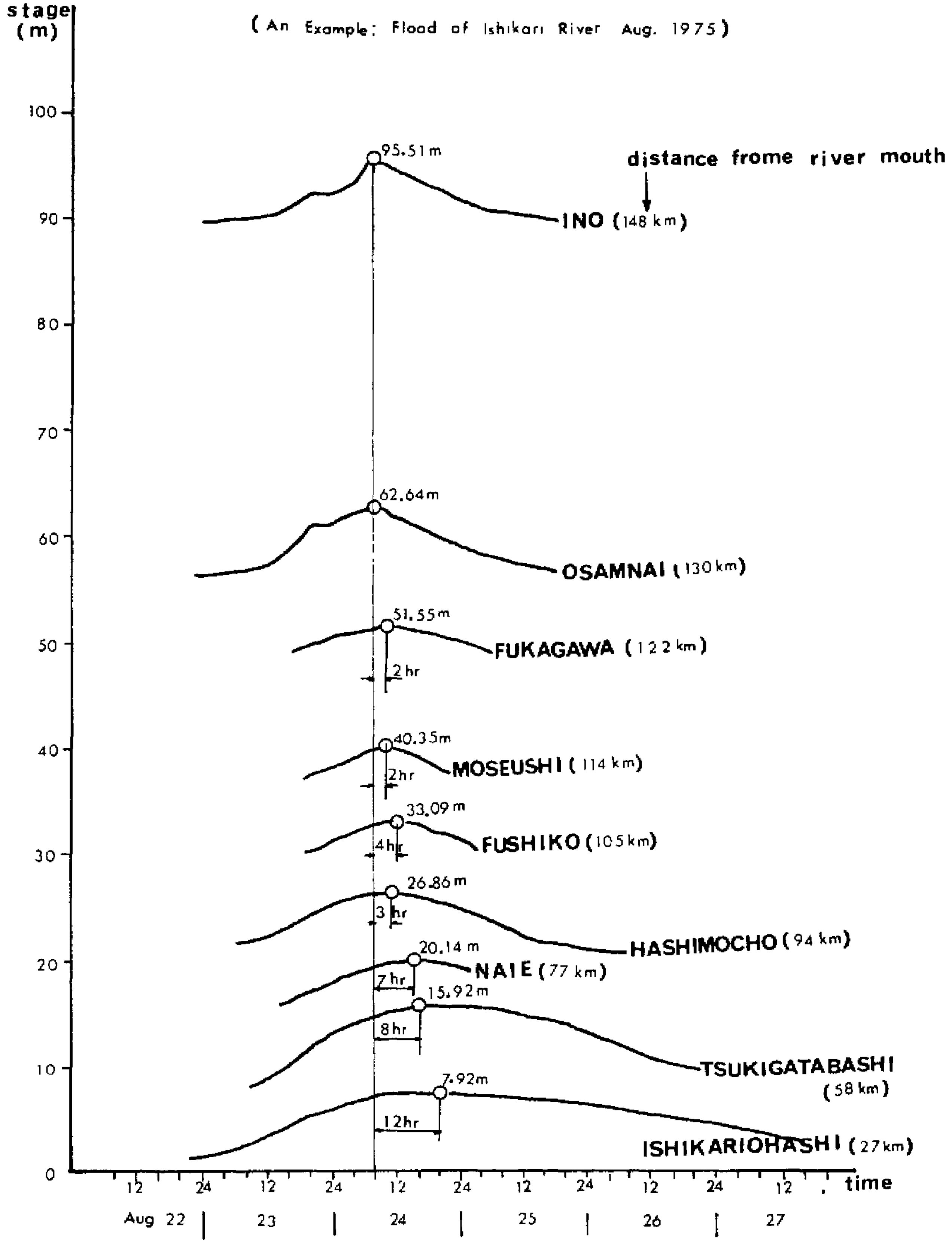


Fig.4 An Example on the Characteristic Changes of Flood Runoff due to Urbanization

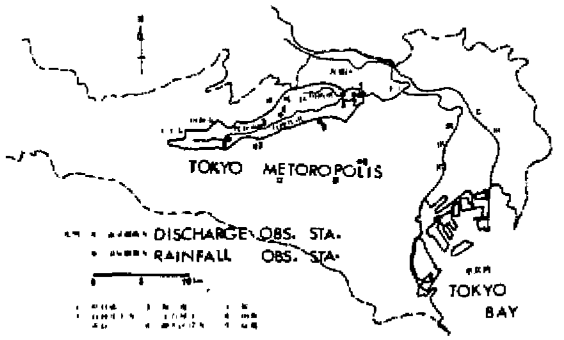
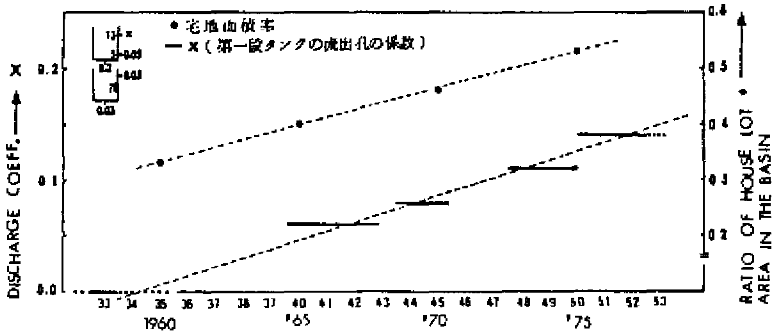


Fig.4-a The location of the Shakujii River basin

Fig.4-b The changes of discharge coeff. of the upper orifice of first tank (X) corresponding to the increase of house lot area ratio in the Shakujii River basin



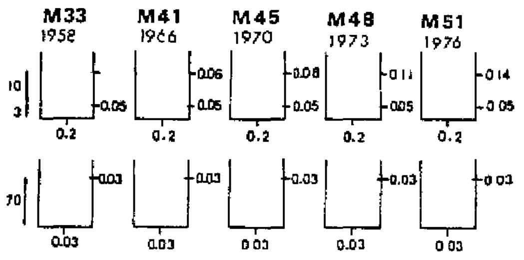


Fig.4-c Structural changes of tank model due to urbanization in the Shakujii River basin

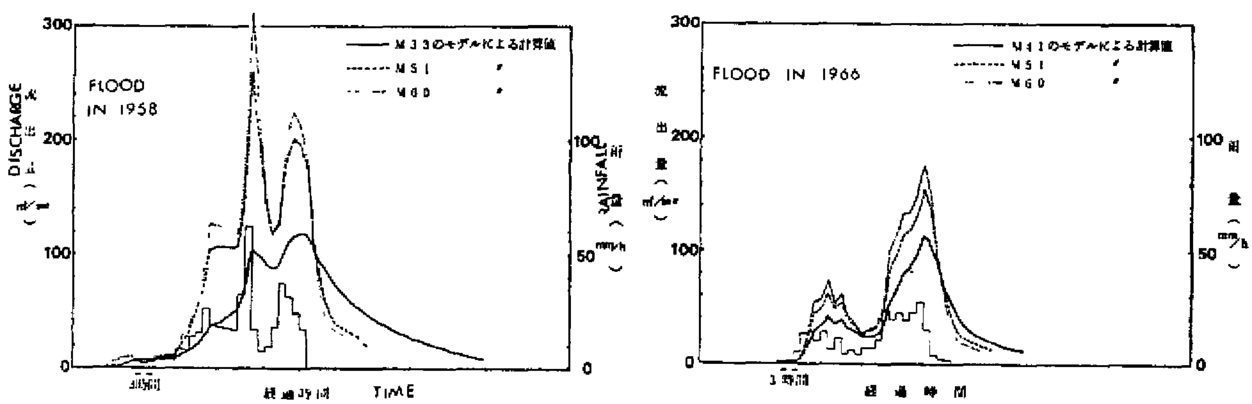


Fig.4-d Comparison of flood runoff changes due to urbanization by simulation method using analysed tank models

Fig.- 6 River Improvement works in the Tone River System Carried Out by Tokugawa Shogunate

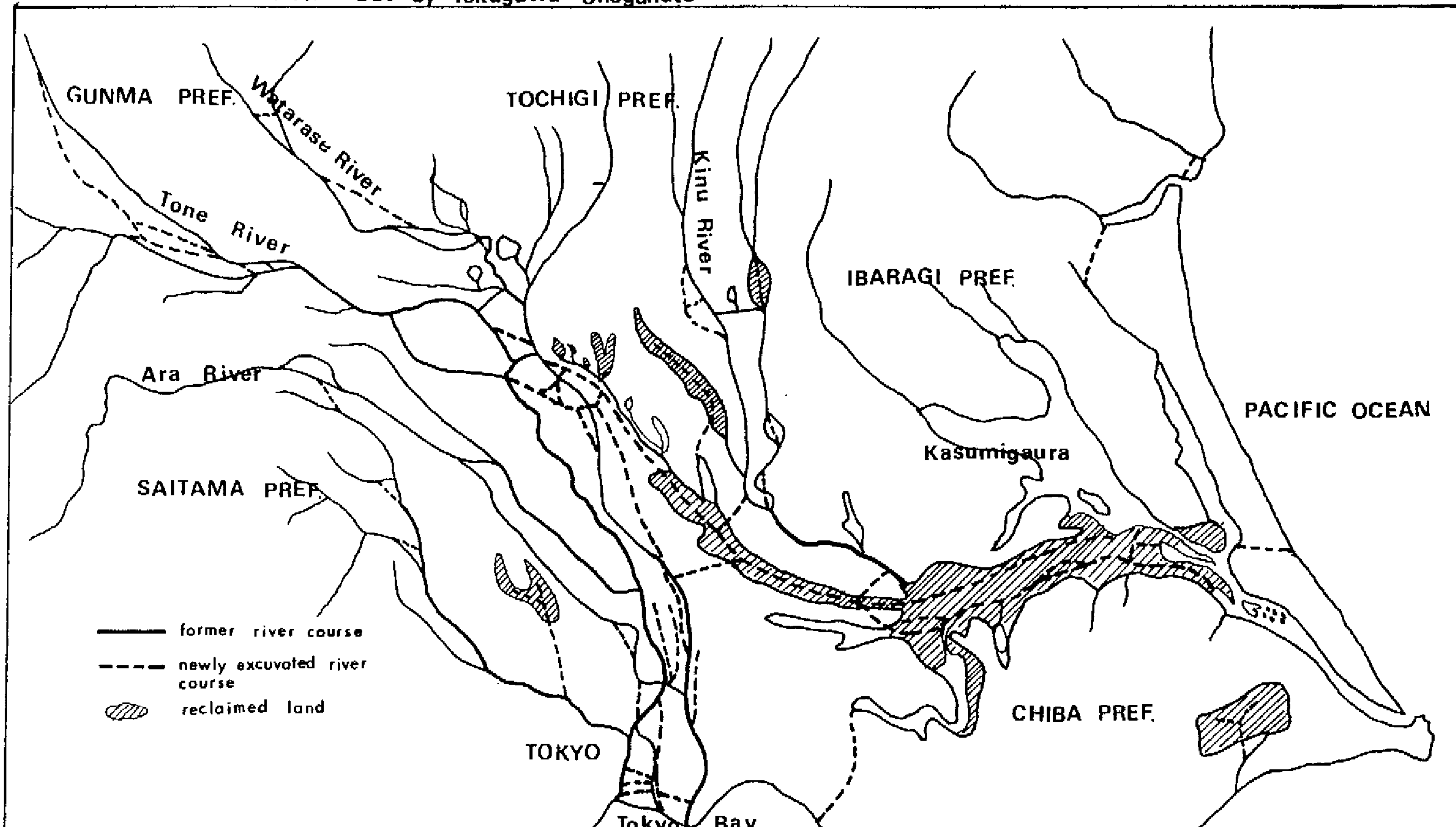


Fig.- 7 Circular Levees in the Downstream Area of Kiso River at Early Meiji Era

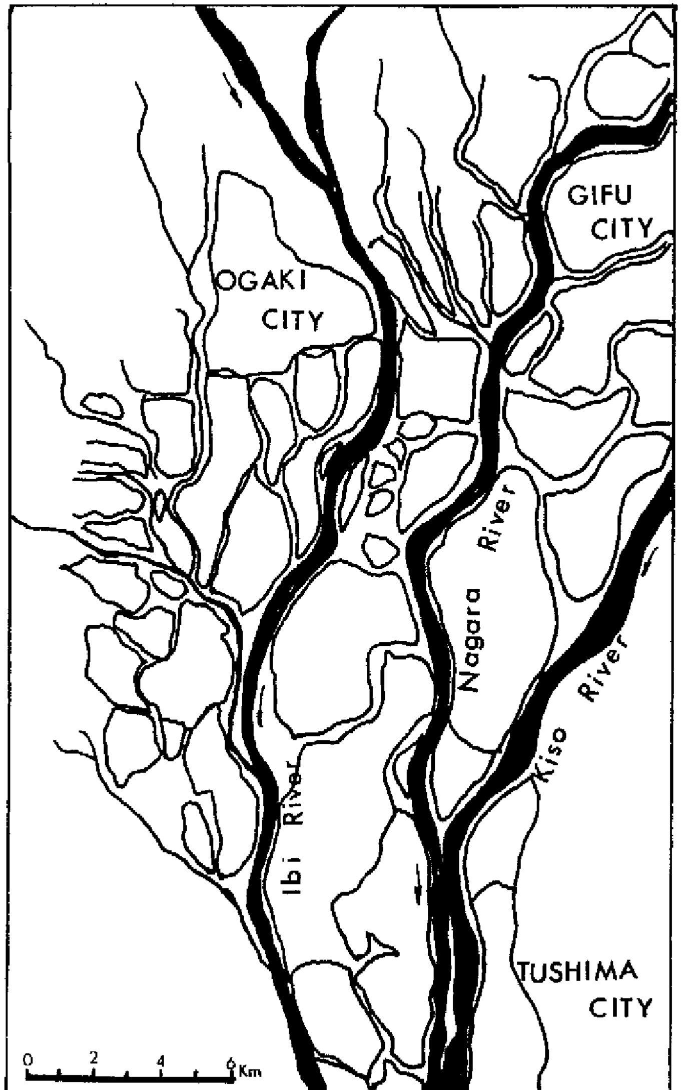


Fig.- 5 River Improvement Works of Kamanashi River in the 16th Century

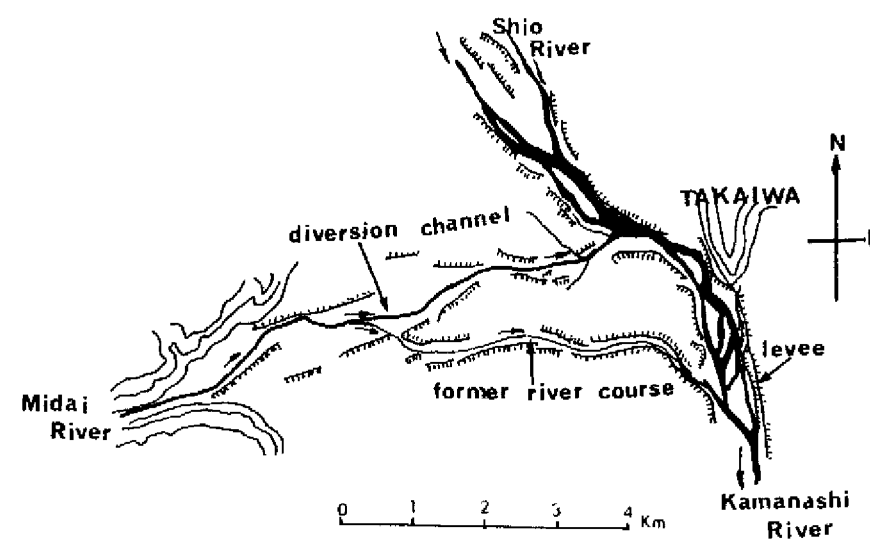


Fig.- 8 River Improvement Works of Ishikari River Centering on Cutoff and Levee

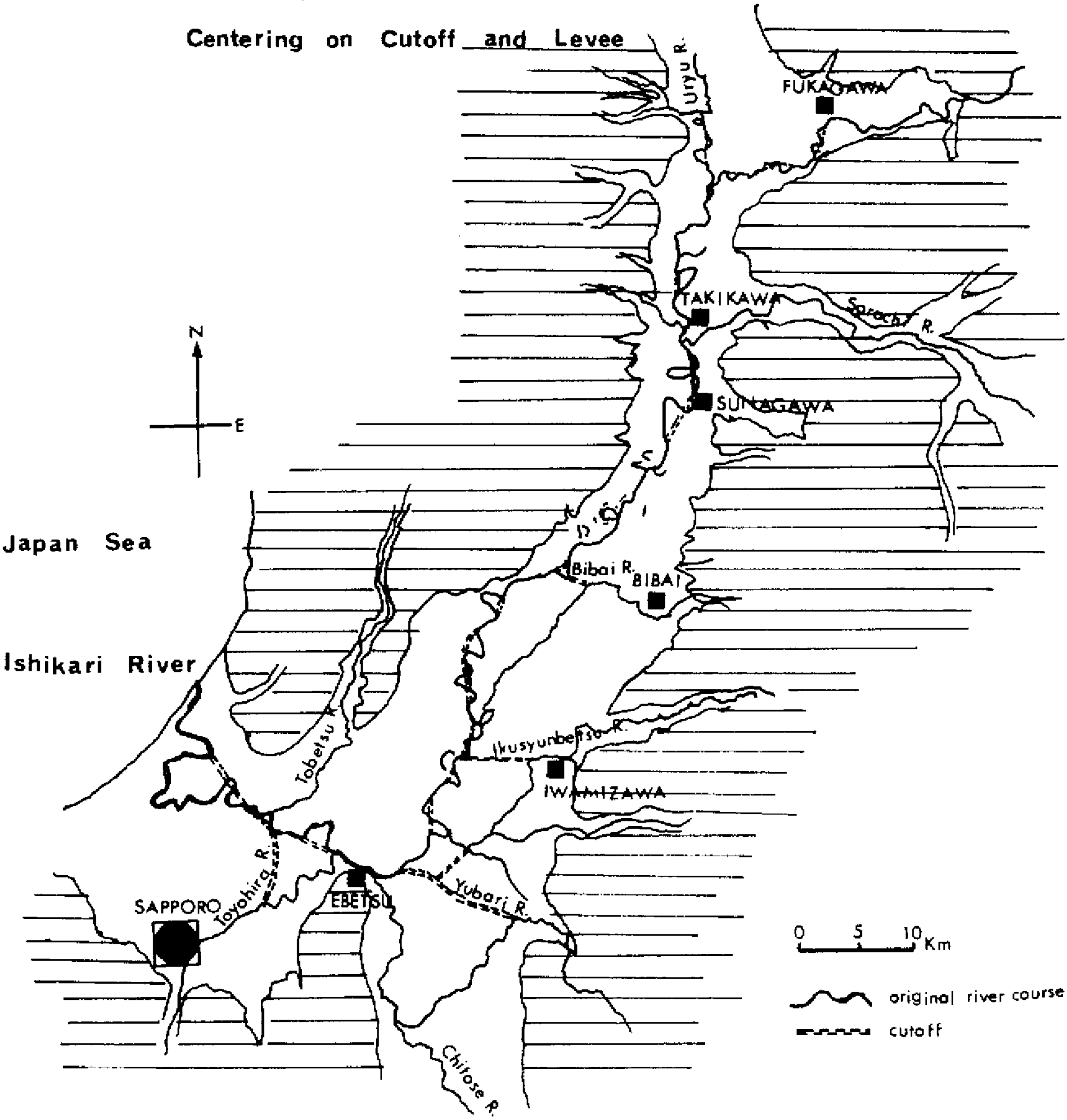


Table 1 Flood losses in the countries of the ESCAP region

country	sufferers from flood hazard (1,000 persons)				dead and missing (person)				damage cost (U.S.$ million in 1975)				
	1976	1977	1978	1979	1976	1977	1978	1979	1976	1977	1978	1979	'65-'79 mean
Australia	-	-	-	-	2	5	12	38	102	2	62	42	76
Bangladesh	-	($813x10^3$ households)	-	-	46	733	-	-	-	13.5c	-	-	324
Hong Kong	2.4	0.2	3.6	15.7	20	-	18	343	-	-	1.9c	3.6c	3.1c
India	37,200	44,600	68,000	18,314	1,464	10,000	2,510	3,634	1,181	1,294	1,267	674	712
Indonesia	239.3	286.2	189.3	-	244	135	59	2,240	-	-	-	-	-
Malaysia	2.2	4.5	-	-	-	7	-	10	0.8	0.4	2.2	1.4	3.7
Philippines	3,253	($60x10^3$ households)	1.1	-	347	166	1,057	210	80	235	171	38	76
Republic of Korea	-	72.4	21.8	-	485	297	120	536	23	88	38	217	61
Thailand	-	-	-	-	57	-	106	48	5	7	169	2	33
Japan	-	12.2	-	-	234	54	51	188	3,583	922	985	2,202	1,755

Data: Water Resources Journal (1977-1980 June). The data of Japan depend on other domestic sources.
Note: Flood losses are due to syclones, typhoons, storms and floods, and damage cost is due to tropical cyclones, heavy rains and floods.

Table 2 Flood damage in the countries of ESCAP region

country	average annual damage cost per head (U.S.$)	rate of average annual damage cost for GNP (%)		flood losses and their percentage in average annual damage cost (%)					period
		mean	max.	agricultural products	industrial assets	individual assets	public facilities	pub.service assets *	
Auatralia	0.21	0.01	0.05	32	14	18	18	18	61-70
New Zealand	0.99	0.04	0.11	-	-	72	28	-	61-70
Indonesia	0.03	0.03	0.10	-	-	-	-	-	62,63,66,68
Pakistan	1.02	0.97	1.71	-	-	-	-	-	61-66, 68,69
India	0.42	0.33	0.61	65	-	12	23		61-70
Burma	0.02	0.01	0.03	14	-	-	85	1	63,66,67,68
Malaysia	0.34	0.09	0.42	31	-	7	62	-	63-69
Singapore	0.26	-	-	22	40		16	22	67-69
Sri Lanka	0.37	0.27	2.43	40	25	20	7	8	64.66,69
Hong Kong	0.23	-	-	-	-	-	100		61-70
Philippines	0.80	0.43	2.04	42	-	-	54	4	61-70
Taiwan	0.64	0.44	1.24	62	-	25	13	-	61-70
Republic of Korea	1.16	0.76	1.51	38	8		51	3	61-70
Japan	5.95	0.42	1.53	7	10	16	66	1	61-70

Data: Water Resources Journal, Dec. 1973 Note: Damage is only due to floods

* : The figure includes the percentage for damage of relief sector.

Table 3 Detailed informations on the disasters illustrated in Section 3

pattern of flood hazard and disasters	affected area	observed maximum 1) rainfalls (mm)			losses and damage 2)			main causes of disaster
		max. total	max. daily	max. hourly	deaths & missings	houses destroyed	damage of agri. land	
					(person)	(house)	(ha)	
1. flood hazards in the headwaters area								
(1) F.D. at Ashiwada typ.6626, Sept.'66	Yamanashi & Shizuoka Pref.	376	296	83	318	11,734	34,159	landslides mudflows
(2) F.D. at Shirakawa, typ.6807, Aug.'68	Gifu & Nagasaki Pref.	382	382	90	133	193	1,946	landslides mudflows
(3) F.D. at Shōdojima, typ.7617, Sept.'76	Hyogo, Gifu & Kagawa	1,306	758	93	169	2,833	88,965	flush floods mudflows
2. flood hazards on the valley & alluv. fan								
(1) F.D. in Kano R. B. typ.5822, Sept.'58	Chūbu & Kantō	753	691	120	1,157	4,708	89,839	flush floods mudflows
(2) F.D. at Nagasaki, bai-u fr.Jul.'82	Kyūshū	608	531	187	345	53,106	15,354	floods, land-slides & mudflows
(3) F.D. in W.Shimane bai-u fr.Jul.'83	Shimane & Yamaguchi Pref.	555	330	91	113	24,524	7,143	floods, land-slides & mudflows
3. flood hazards in the alluvial plain								
(1) F.D. in Tone R.B. typ.4709, Sept.'47	Kantō & Tōhoku	611	360	67	1,529	12,761	303,659	floods
(2) F.D. in Chikugo R.B. bai-u fr.June'53	Kyūshū, Shiko-ku & Chūgoku	1,060	500	70	1,013	17,370	269,810	floods
(3) F.D. in Ishikari R. B.typ.7506, Aug.'75	Hokkaidō & Shikoku	1,107	505	116	32	710	80,033	floods, landslides
(4) F.D. in Nagara R.B. typ.7617, Sept.'76	Gifu, Hyōgo & Kagawa Pref.	(same as 1.(3))						
4. flood hazards in coastal areas								
(1) Isewan Typoon typ.5915, Sept.'59	whole country except Kyūshū	567	301	64	5,101	153,893	204,307	storm surge floods

Notes: 1) The observed maximum rainfalls are chosen from the data at many gaging stations located in the affected areas , therefore, they are not always observed at a same station.
2) The numbers of losses and damage are the total ones reported from all affected areas.

Table-4 Comparison of Specific Flood Discharge of Major Rivers

river	site	catchment area (A)	flood discharge (B)	specific flood discharge (B/A)
		km^2	m^3/sec	$m^3/sec/km^3$
Ishikari	(Japan) Ishikari Oohashi	12,697	8,620	0.68
Kitakami	(") Kozenji	7,060	8,580	1.22
Tone	(") Yattajima	5,150	17,000	3.30
Kiso	(") Inuyama	4,684	13,767	2.94
Yodo	(") Hirakata	7,281	7,800	1.07
Shinano	(") Ojiya	9,719	9,181	0.94
Yoshino	(") Iwazu	2,768	15,000	5.42
Donau (Danube)	(Austria) Vienna (Wein)	101,600	10,500	0.103
Rhône	(France) Lyon	19,267	5,600	0.291
Rhine	(West Germany) Linz	140,039	10,900	0.078
Elbe	(East Germany) Dresden	53,100	4,600	0.087
Odra (Oder)	(Poland) Wroclaw (Breslau)	22,600	2,450	0.108

Table-5 Area, Population and Total Assets in the protected Areas from Flood in Japan

	1960	1970	1985 (assumed)
area subject to flooding	31,020 km^2	36,519 km^2	36,519 km^2
population	(10^3 persons)		
whole country	93,419 (100%)	103,704 (100%)	121,000 (100%)
in the area subject to flooding	38,199 (40.9)	54,338 (52.4)	77,000 (63.6)
density of population	(persons/km^2)	(persons/km^2)	(persons/km^2)
whole country	253	281	327
in the area subject to flooding	1,227	1,488	2,108
assets in the area subject to flooding	(10^{12} yen) 31	(10^{12} yen) 114	(10^{12} yen) 520
its density	(10^9 yen/km^2) 1.1	(10^9 yen/km^2) 3.1	(10^9 yen/km^2) 14.2

Note; assets are estimated at the price level of 1970 and include facilities for flood protection

Table-6 Increase of Flood Loss due to Urbanization
(three examples in the Tokyo Metropolitan Area)

river basin	date and cause	amount of rainfall	number of inundated houses	
			upper floor	under floor
Shiba River	1958, typhoon 5822(Ida, Kanogawa Typhoon)	280 mm/day	11,500	29,900
(Saitama Pref.)	1966, typhoon 6604(Kit)	267 "	17,400	47,500
Kashio River	1961 June, bai-u front	219 "	10,100	28,900
(Kanagawa Pref.)	1966, typhoon 6604(Kit)	229 "	15,400	51,400
Tsurumi River	1958, typhoon 5822(Ida, Kanogawa Typhoon)	321 mm/total	16,900	48,700
(Kanagawa Pref.)	1966, typhoon 6604(Kit)	278 "	15,400	51,000

Table 7 Revision of design flood discharge corresponding to increasing flood discharge due to river basin development (examples of 6 major rivers in Japan)

river	site	catchment area	process of revision of design flood discharge			recorded flood discharge	
			No	year	D.F.D	year	F.D.
Ishikari	Ishikari Oohashi	12,697 Km^2			m^3/sec		m^3/sec
			1	1909	8,350*	1904	8,350
			2	1964	(9,300) 9,000	1975	8,620
			3	1982	(18,000) 14,000		
Kitakami	Kozenji	7,060	1	1941	(7,700) 5,600	1913	5,700
			2	1949	(9,000) 6,300	1947	8,580
			3	1973	(13,000) 8,500	1948	7,450
Tone	Yattajima	5,114	1	1900	3,750	1947	17,000**
			2	1910	5,570	1958	9,800
			3	1939	10,000	1959	9,070
			4	1949	(17,000) 14,000		
			5	1981	(22,000) 16,000		
Shinano	Ojiya	9,719	1	1887	4,730	1914	9,184
			2	1941	9,000	1958	6,242
			3	1974	(13,500) 11,000	1969	6,105
Yodo	Hirakata	7,281	1	1885	5,560	1917	7,240
			2	1937	(8,650) 6,950	1953	7,800
			3	1971	(17,000) 12,000	1961	7,800
Kiso	Inuyama	4,684	1	1887	7,350	1897	13,767
			2	1921	9,738	1898	11,000
			3	1968	(16,000) 12,500	1938	12,385

Note: The figure in ( ) means basic design flood discharge which includes the discharge to be controlled by dams.

* at the river mouth. ** assumed discharge taking into account of flooding water.

Table - 8 Flood Control Dams in Japan

Organization	Ministry of Construction	Water Resources Development Corporation	Prefectural Governments	Total
Number of dams constructed until 1978	48	13	141	202
Expenditure (10^9 yen)	390.3	242.1	417.7	1,050.1
(10^6 dollar)*	1,561.4	968.4	1,670.7	4,200.4
Effectiveness				
a. flood control				
inflow(1,000 m^3/s)	76	34	106	216
controled(")	40	13	50	103
annual average saving cost for flood damage (10^9 yen)	14.49	1.48	17.43	33.40
(10^6 dollar)	58.0	5.9	69.7	133.6
b. annual total of power generation (10^6 MWH)	5.55	1.53	5.12	12.21
c. municipal water supply (10^6 m^3/day)	3.34	6.41	5.37	15.17
d. industrial water supply (10^6 m^3/day)	1.99	5.25	3.51	10.76
Number of dams under construction in 1979 F.Y.	75	15	193	283

* change rate of yen to dollar: 250 yen VS. 1 dollar