Tone-gawa

Map of River

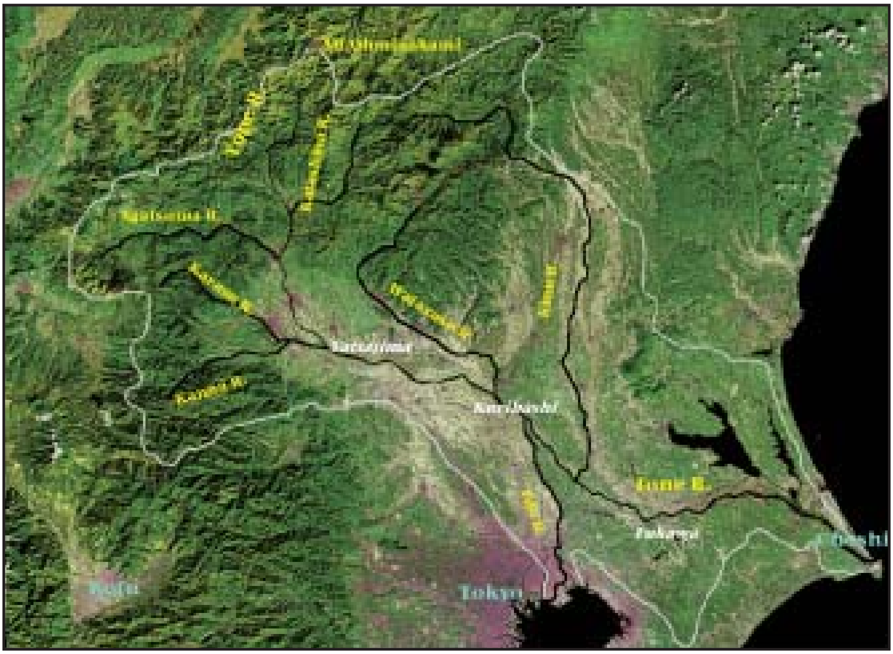


Table of Basic Data

Name: Tone-gawa		**Serial No.:** Japan-11
Location: Central Honshu, Japan	N 35° 32' - 37° 5'	E 138° 24' - 140° 51'
Area: 16,840 km^2	**Length of main stream:** 322 km	
Origin: Mt. Ohminakami	**Highest point:** 1,834 m (trunk of Tone-gawa)	
Outlet: Pacific Ocean	**Lowest point:** River mouth (0 m)	
Main geological features: Mountain area: sandstone, slate, limestone from the Paleozoic and Mesozoic eras, and volcanic rock, Plain area: Pleistocene and alluvium		
Main tributaries: Katashina-gawa (676.1 km^2), Agatsuma-gawa (1,355.2 km^2), Kanna-gawa (417.6 km^2), Kabura-gawa (632.4 km^2), Karasu-gawa (759.1 km^2), Watarase-gawa (2,621.4 km^2), Kokai-gawa (1,043.1 km^2), Kinu-gawa (1,760.6 km^2)		
Main lakes: Kazumigaura, Kitaura, Chuzenji-ko, Imba-numa, Tega-numa, Ushiku-numa		
Main reservoirs: Yagisawa (115.5 x 10^{6}m^3, 1967), Naramata (85.0 x 10^{6}m^3, 1991), Hujiwara (31.0 x 10^{6}m^3, 1958), Aimata (20.0 x 10^{6}m^3, 1959), Sonohara (13.2 x 10^{6}m^3, 1966), Shimokubo (120.0 x 10^{6}m^3, 1969), Ikari (32.0 x 10^{6}m^3, 1956), Kawamata (73.1 x 10^{6}m^3, 1965), Kawaji (76.0 x 10^{6}m^3, 1983)		
Mean annual precipitation: 1162.6 mm at Maebashi, 1580.1 mm at Choshi (1971 - 2000).		
Mean annual runoff: 165.2 m^3/sec at Yattajima, 220.6 m^3/sec at Kurihashi (1960 - 2000)		
Population: about 12,000,000	**Main cities:** Maebashi, Takasaki, Saitama, Tsukuba Utsunomiya	
Land use: Forest (45.5%), Paddy field (18.2%), Cropland (11.2%), Orchard (3.3%), Urban (3.7%), Residential area (6.4%), Water surface (5.1%), Other (6.6%)		

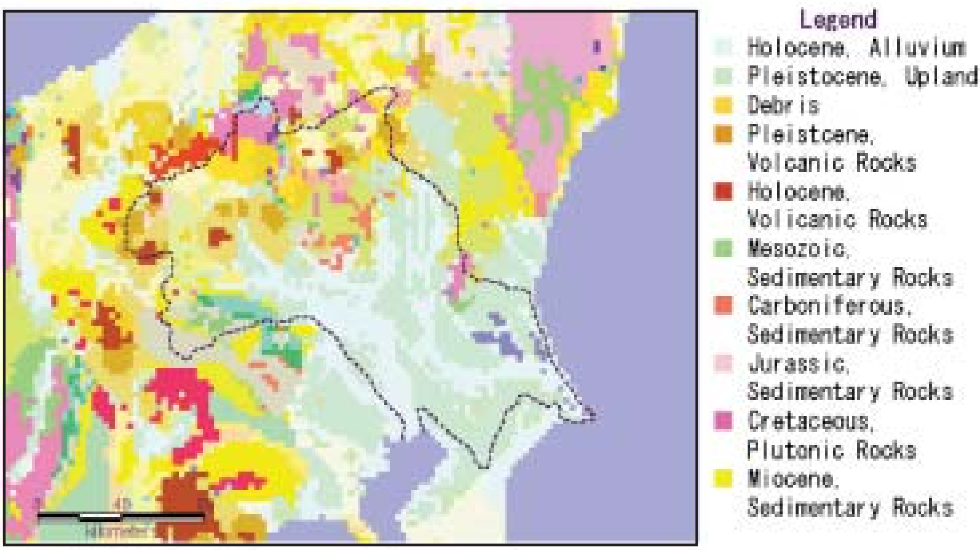
1. General Description

The Tone River (Tone-gawa) has the largest catchment area (16,840 km^2) and the second longest main river channel (322 km) in Japan. The river originates at Mt. Ohminakami in the Echigo Mountains and runs across the Kanto Plain, the largest plain in Japan. The ancient Tone River flowed to Tokyo Bay. During the "Eastward Transfer Project" carried out by the Tokugawa Shogunate in the Edo era (1603-1867) its course was shifted during the 17th century. The present Tone River flows out to the Pacific Ocean at Choshi City. The Kanto Plain includes the capital of Japan, Tokyo, and the Tokyo Metropolitan area has been expanding into the plain. Although the catchment area of the Tone River occupies only 4.5% of the land area of Japan, about 10% of the Japanese population live in the catchment. The high population density of the basin increases the importance of the Tone River in Japan.

Modern river management in the basin started in the Meiji era (1868-1912). Since then there have been unprecedented floods in the basin, and the design flood flow has been revised several times after large floods. In 1947, Typhoon Kathleen brought heavy rainfall, and embankments broke in the middle reaches of the Tone River. The resultant flooding extended to Tokyo, and caused great damage to the Tokyo Metropolitan area. One of the causes of the flooding is urbanization of the Tokyo Metropolitan area. The population of Tokyo and the prefectures in Kanto District was about 10,000,000 in the Meiji era. However, since then it has increased to about 30,000,000, and property values have increased very much. Demand for the available water resources has also increased, and recent droughts have caused serious social problems.

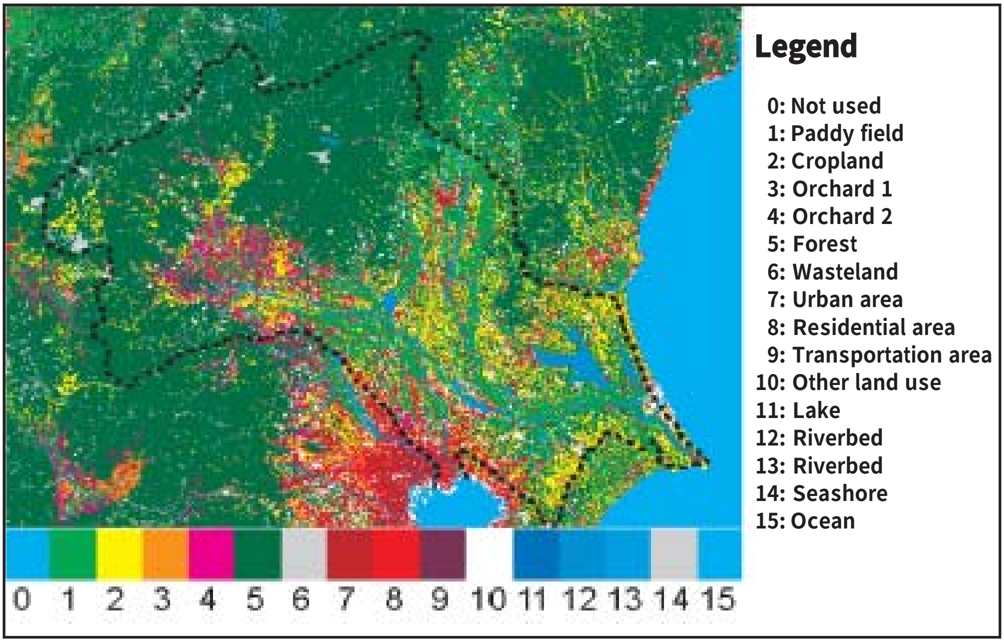
2. Geographical Information

2.1 Geological Map



* Based on the Geological Map of Japan 1:1,000,000, 3rd Edition CD-ROM, Geological Survey of Japan.

2.2 Land Use Map

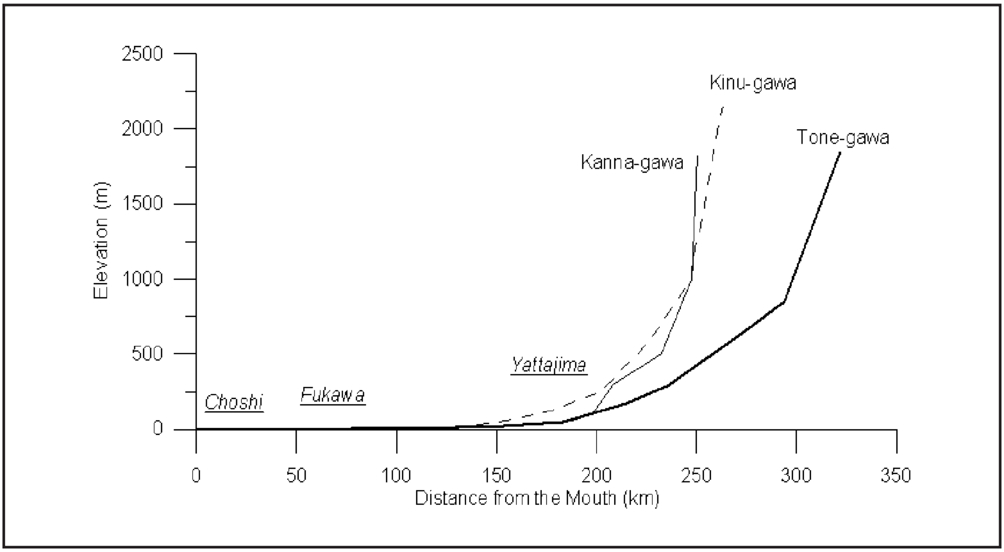


* Based on the National Land Information, National Land Agency, Japan

2.3 Characteristics of River and Main Tributaries

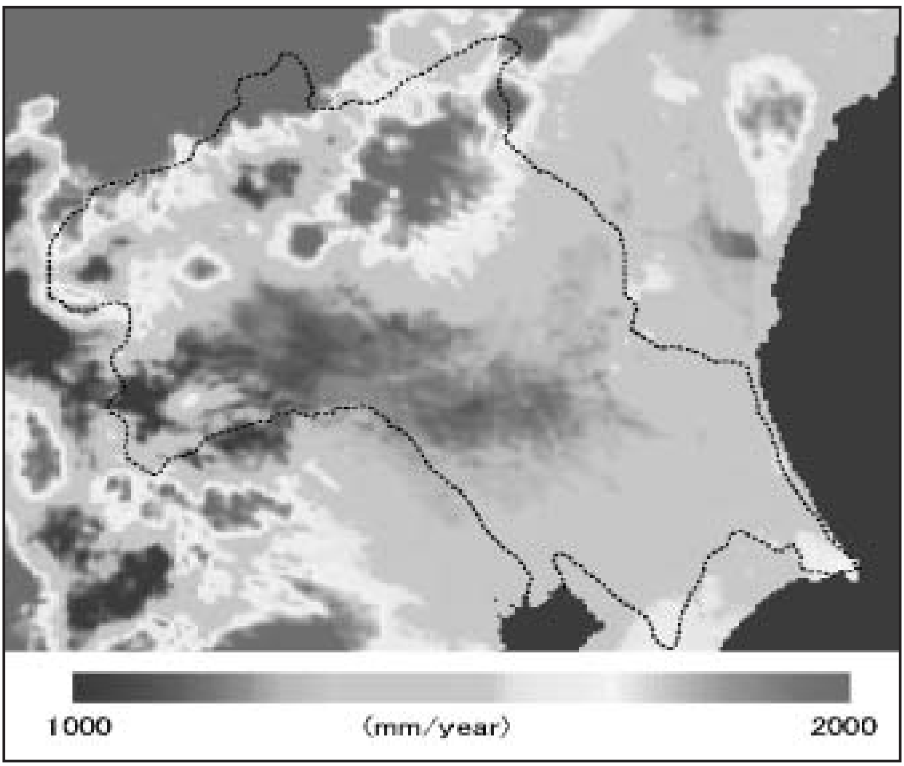
No.	Name of river	Length [km] Catchment area [km^2]	Highest peak [m] Lowest point [m]	Cities Population (1997)
1	**Tone** (Main river)	322 16,840	1834 0	Ohmiya, Tsukuba (435,463), (150,351)
2	**Katashina** (Tributary)	60.8 673.3	2163 288.5	Numata (47,378)
3	**Agatsuma** (Tributary)	76.2 1,352	1362 169.9	Shibukawa (48,385)
4	**Karasu** (Tributary)	61.8 470	1654 56.6	Takasaki (238,228)
5	**Kanna** (Tributary)	87.4 407	1818 64	Fujioka (63,516)
6	**Watarase** (Tributary)	107.6 2,621.4	2144 13	Kiryu, Ashikaga (119,559), (164,841)
7	**Kinu** (Tributary)	176.7 1,760.6	2141 7	Utsunomiya, Nikko (434,770), (18,837)
8	**Kokai** (Tributary)	111.8 1,043.1	185 5	Shimodate, Mouka (66,125), (61,754)

2.4 Longitudinal Profiles



3. Climatological Information

3.1 Annual Isohyetal Map and Observation Stations



* Based on the National Land Information, Ministry of Land, Infrastructure and Transport, Japan

3.2 List of Meteorological Observation Stations

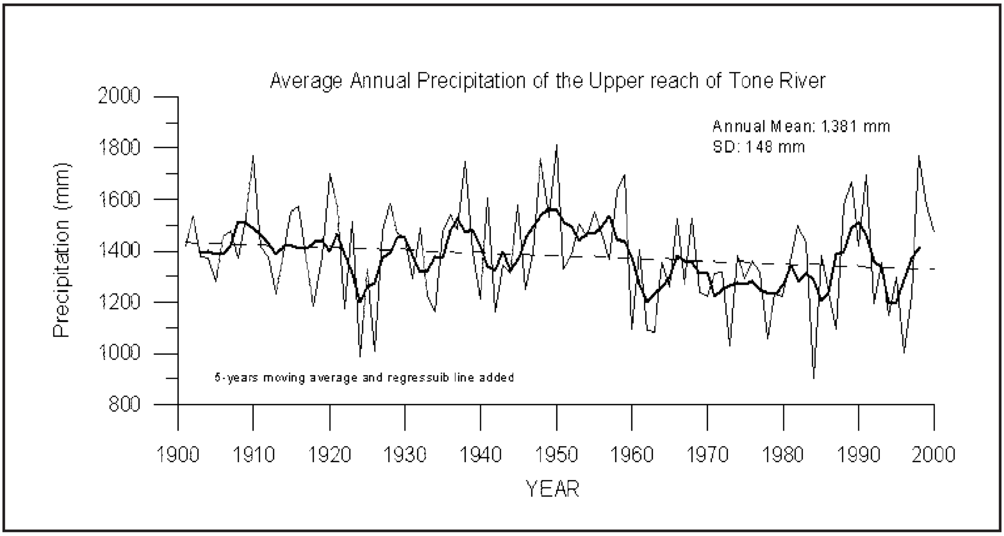
No.	Station	Elevation [m]	Location	Observation period	Mean annual precipitation [mm]	Mean annual temperature [°C]	Observation items[1)]
42046 *	Fujiwara	700	N 36° 51.9' E 139° 3.8'	21	1,801.7	8.7	A
42091 *	Minakami	520	N 36° 47.8' E 138° 59.7'	103	1,692.3	10.2	A
42121 *	Kusatsu	1,230	N 36° 36.9' E 138° 35.6'	103	1,689.7	7.4	A
42146 *	Numata	430	N 36° 39.0' E 139° 3.9'	103	1,084.8	11.4	A
42221 *	Tashiro	1,230	N 36° 27.6' E 138° 27.9'	21	1,482.7	7.1	A
42286 *	Kamisatomi	180	N 36° 22.5' E 138° 53.9'	21	1,329.2	13.3	A
47624 **	Maebashi	112.1	N 36° 24.1' E 139° 3.8'	30	1,162.6	14.2	M
47626 **	Kumagaya	30.0	N 36° 8.8' E 139° 23.0'	30	1,243.2	14.6	M
47615 **	Utsunomiya	119.4	N 36° 32.8' E 139° 52.3'	30	1,443.4	13.4	M
47648 **	Choshi	20.1	N 35°44.2' E 140° 51.6'	30	1,580.1	15.3	M

* Serial Number used by JMA (Japan Meteorological Agency).
** Serial Number used by WMO (World Meteorological Organization).
1) A: The AMeDAS (Automatic Meteorological Data Acquisition System) established in 1979. Some stations have long term records before the installation of the AMeDAS system. The observation items are precipitation, air temperature, wind speed, wind direction and sunshine duration.
M: Meteorological Observation, JMA, records 14 items including precipitation, air temperature, sunshine duration, solar radiation, wind speed, wind direction.

3.3 Monthly Climate Data

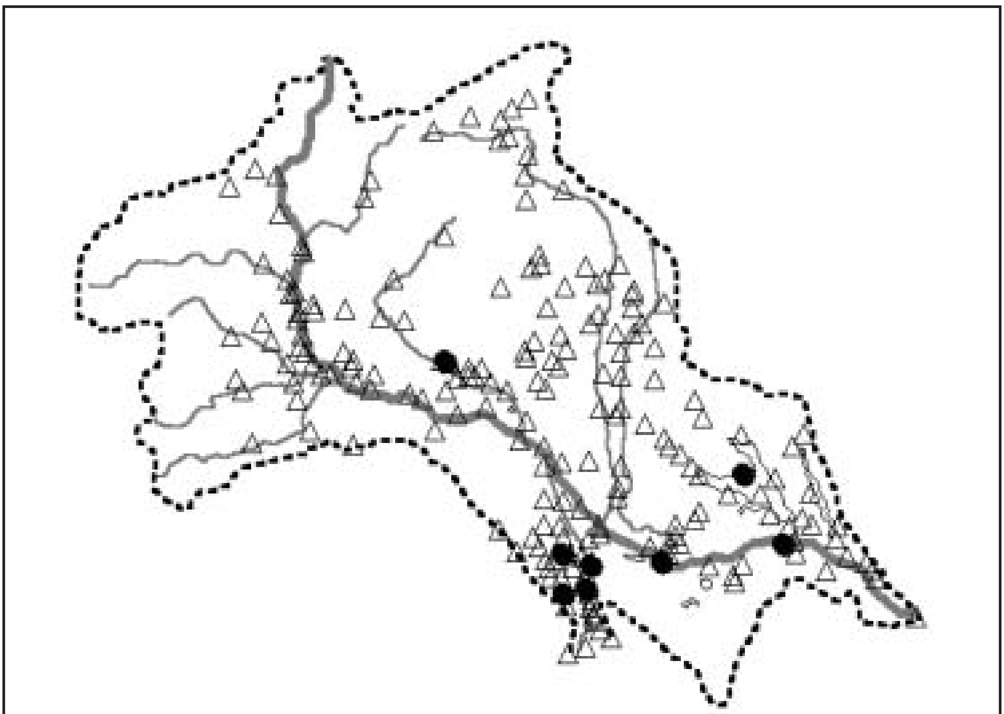
Observation Item	Observation station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Period for the mean
Temperature [°C]	Maebashi	3.3	3.6	6.9	12.9	17.7	21.2	24.7	26.1	21.9	16.1	10.5	5.8	14.2	1971 - 2000
Precipitation [mm]	Maebashi	20.8	33.0	56.3	78.7	90.7	151.4	183.0	184.7	214.8	93.4	42.7	13.2	1,162.6	1971 - 2000
Solar radiation [MJ/m^2/d]	Maebashi	9.4	11.7	14.4	16.1	17.3	13.9	14.4	14.8	11.1	10.5	9.0	8.4	12.6	1971 - 2000
Duration of Sunshine [hr]	Maebashi	203.9	186.1	202.8	187.4	193.7	119.0	135.2	162.8	116.8	158.1	173.3	198.6	2,037.7	1971 - 2000

3.4 Long-term Variation of Monthly Precipitation



4. Hydrological Information

4.1 Map of Streamflow Observation Stations



Locations for the telemetric water level (open triangle) and water quality (filled circle) stations were chosen by the Foundation of River and Basin Integrated Communications (FRICS). The Ministry of Land, Infrastructure and Transport operates 355 water level stations in the Tone River Basin. Some of small stations are not included in the above diagram.

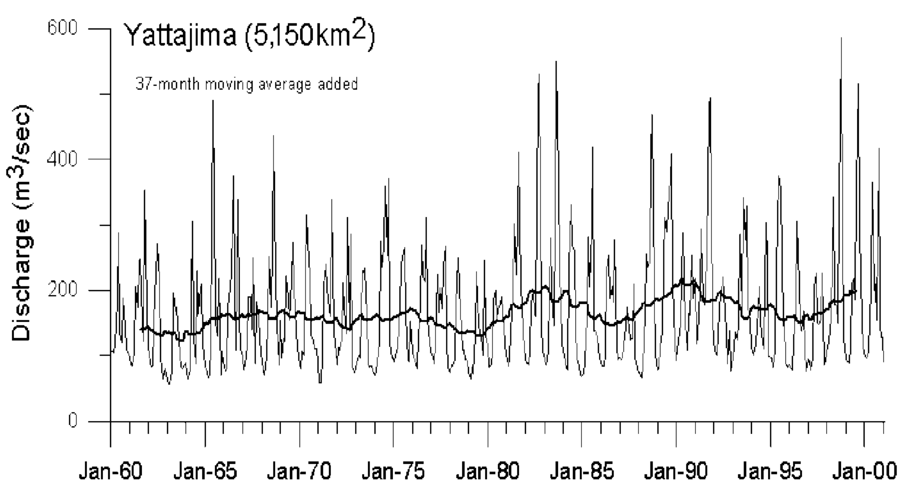
4.2 List of Selected Hydrological Observation Stations

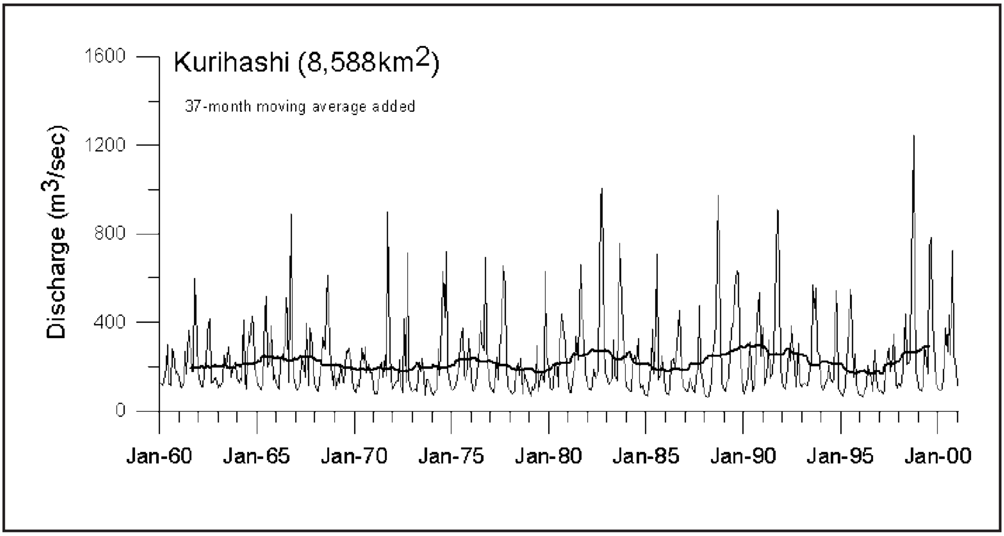
No.*	Station	Location	Catchment area (A) [km²]	Observation period	Observation items[1)]
30302	**Yakatabara**	N 36° 37' 02" E 139° 02' 39"	980.9	1954 - present	Q
30306	**Yattajima**	N 36° 15' 37" E 139° 12' 37"	5,150.0	1951 - present	Q
30404	**Kurihashi**	N 36° 08' 25" E 139° 42' 20"	8,588.0	1938 - present	Q
30506	**Fukawa**	N 35° 50' 59" E 140° 08' 31"	12,458.0	1938 - present	Q, WQ
30602	**Noda**	N 35° 56' 08" E 139° 51' 18"	8,687.9	1955 - present	Q

No.*	$\overline{Q}$[2)] [m³/s]	Qmax[3)] [m³/s]	max[4)] [m³/s]	min[5)] [m³/s]	Q/A [m³/s/100km²]	Qmax/A [m³/s/100km²]	Period of statistics
30302	40.62	1,120	1,254.16	0.02	4.14	114.18	42
30306	158.91	17,000	9,222.35	24.20	3.09	3,300.97	46
30404	250.50	13,000	11,443.50	6.10	2.92	1,513.74	60
30506	221.88	8,170	7,559.39	1.64	1.78	65.58	55
30602	109.93	3,700	1,271.55	23.93	1.27	42.59	44

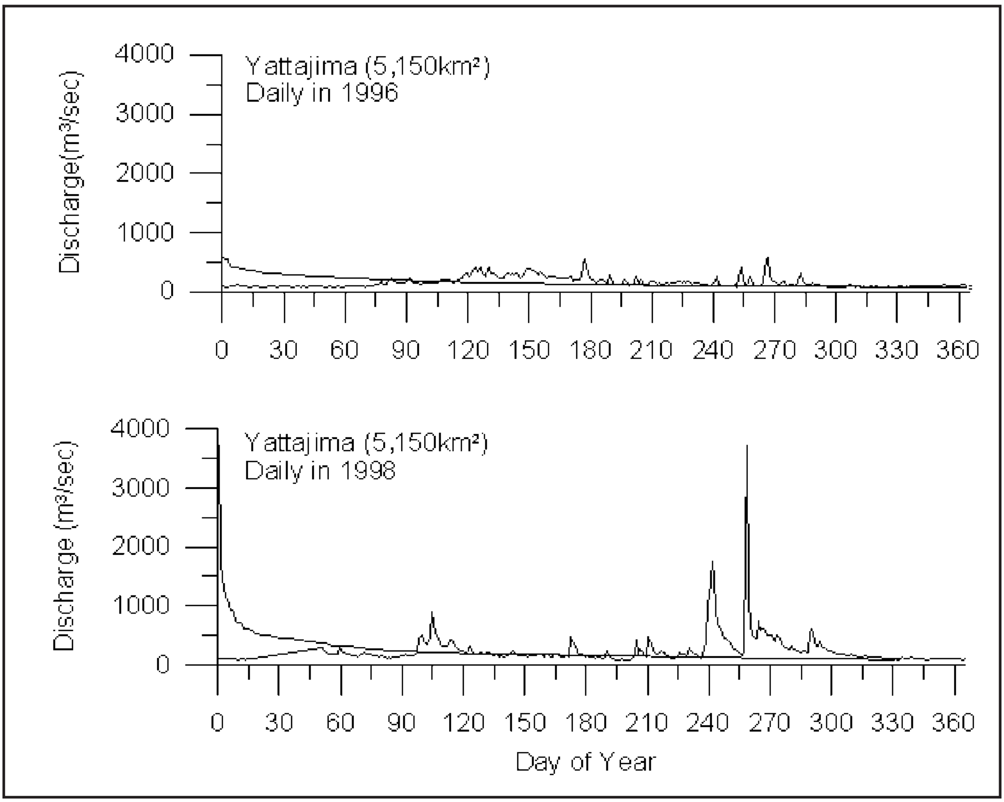
*: Serial number used by The River Bureau, Ministry of Construction
1) Q: Discharge, WQ: Water quality
2) Mean annual discharge
3) Maximum discharge
4) Mean maximum discharge
5) Mean minimum discharge

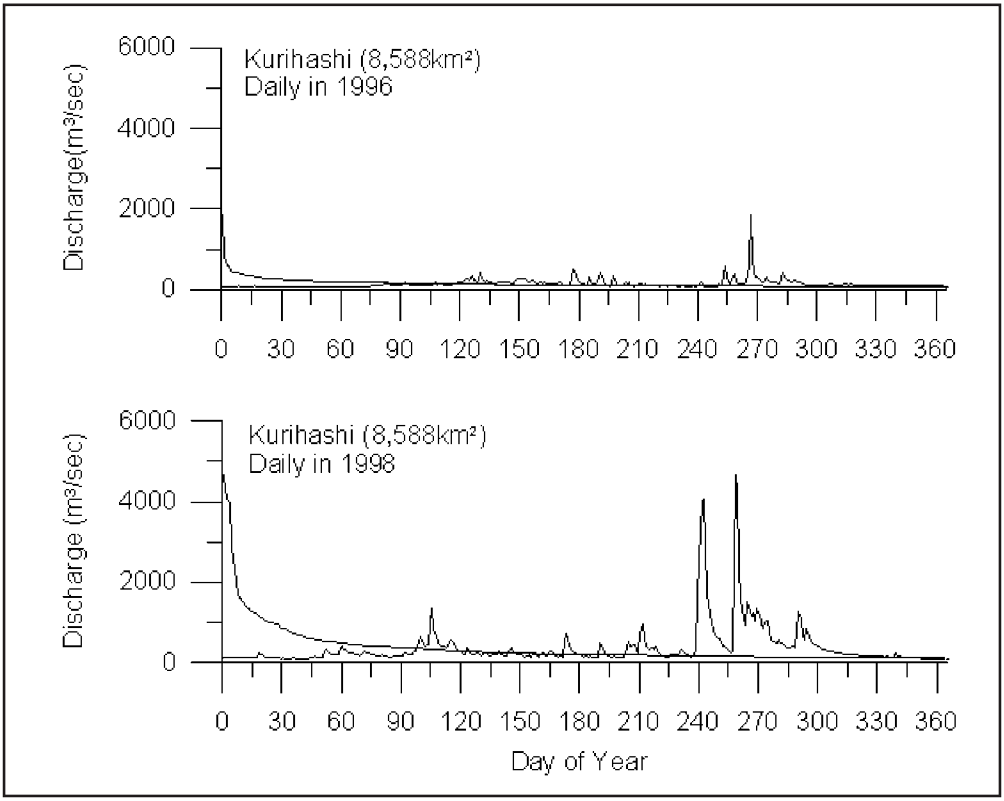
4.3 Long-term Variation of Monthly Discharge





4.4 Annual Pattern of Discharge





4.6 Annual Maximum and Minimum Discharges

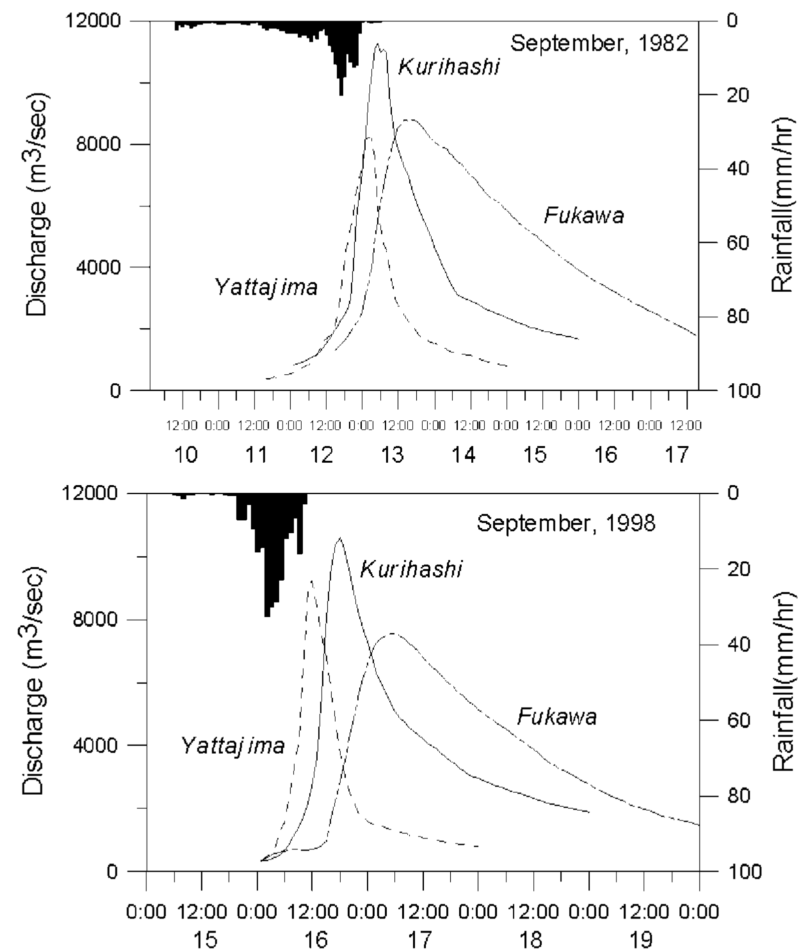
Station: Yattajima [5,150 km^2]

Year	Maximum [m^3/s]	Minimum [m^3/s]	Year	Maximum [m^3/s]	Minimum [m^3/s]	Year	Maximum [m^3/s]	Minimum [m^3/s]
1970	1,043	26.8	**1980**	793	59.1	**1990**	2,841	57.9
1971	2,562	24.2	**1981**	7,690	62.4	**1991**	4,589	84.1
1972	5,370	44.1	**1982**	8,192	59.0	**1992**	946	42.7
1973	808	36.1	**1983**	4,267	60.6	**1993**	1,623	-
1974	5,553	48.9	**1984**	-	-	**1994**	2,758	65.2
1975	1,169	47.3	**1985**	4,077	43.5	**1995**	1,209	47.2
1976	1,876	31.1	**1986**	4,454	55.8	**1996**	1,079	54.8
1977	2,240	52.1	**1987**	781	46.2	**1997**	1,203	55.0
1978	630	44.5	**1988**	3,047	32.0	**1998**	9,222	-
1979	1,738	43.3	**1989**	2,990	43.0	**1999**	5,202	67.5

Station: Kurihashi [8,588 km^2]

Year	Maximum [m^3/s]	Minimum [m^3/s]	Year	Maximum [m^3/s]	Minimum [m^3/s]	Year	Maximum [m^3/s]	Minimum [m^3/s]
1970	859	52.1	**1980**	1,094	54.7	**1990**	4,472	30.8
1971	3,878	46.9	**1981**	7,940	58.1	**1991**	6,543	75.5
1972	6,709	33.2	**1982**	11,444	65.1	**1992**	1,207	67.6
1973	579	37.4	**1983**	5,938	36.1	**1993**	2,583	73.9
1974	4,926	52.6	**1984**	-	-	**1994**	3,157	55.0
1975	1,258	51.1	**1985**	5,648	36.4	**1995**	2,074	43.7
1976	2,107	62.5	**1986**	4,062	50.4	**1996**	2,217	47.2
1977	3,506	61.3	**1987**	1,861	28.3	**1997**	2,176	55.6
1978	1,666	27.0	**1988**	2,368	35.4	**1998**	10,577	71.8
1979	3,631	25.1	**1989**	3,065	55.3	**1999**	6,608	59.1

4.7 Hyetographs and Hydrographs of Major Floods



5. Water Resources

5.1 General Description

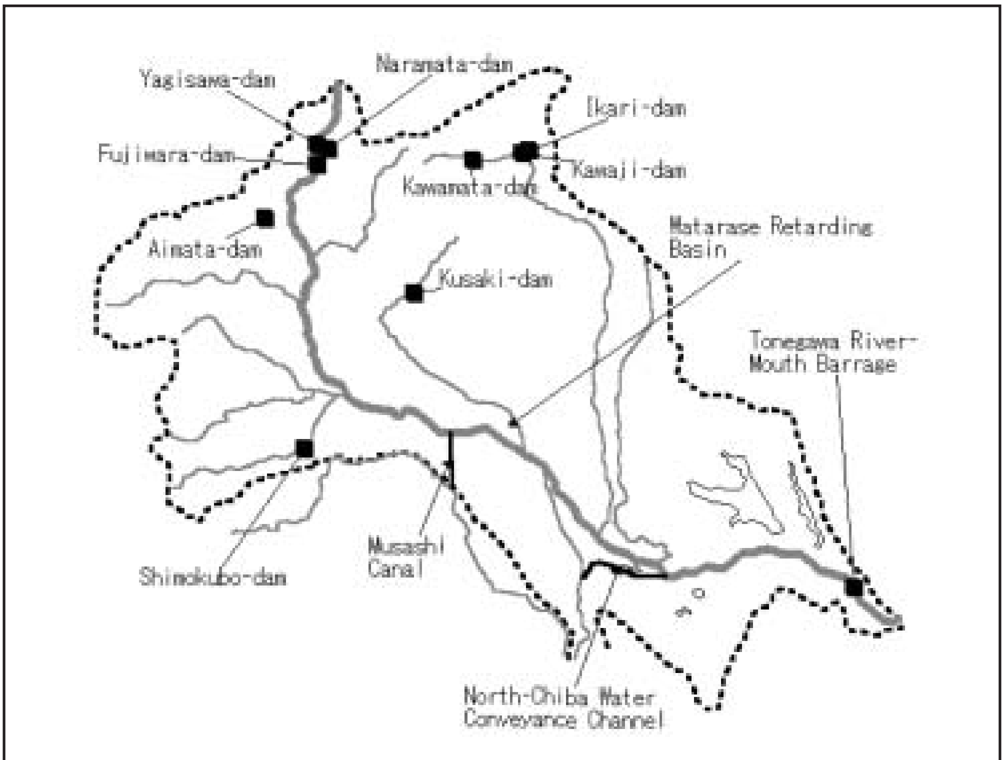
Takasaki City, in 1887, was the first city to use the water resources of the Tone River for domestic water supply. The Tokyo Metropolitan government began by exploiting the water resources of the Tama River catchment. The development of this water resource approached its limit with the completion of Ogouchi Dam in 1957 and so Tokyo had to increase its dependence on the Tone River basin for domestic water. Today, seventy five percent of Toyko's water comes from the Tone River.

Some 88% of the domestic water supply comes from dams located in the upper reaches of the Tone River and its main tributaries. There are eight dams in the headwater regions of the Tone River, and three dams in the Kinu River basin, with a total combined capacity is 642,730,000 m^3.

The water produced from the dams in the Tone River is transferred to the Ara River through the Musashi Canal located in the middle reach of the Tone River, and is then supplied to the Tokyo Metropolitan area for domestic use. Water transferred to the Edo River is taken to the Kanamachi water purification plant, and is used to supply domestic water to the eastern part of Tokyo. The North-Chiba Water Conveyance Channel was constructed to carry water from lower reaches of the Tone River when there is a shortage of water in Tokyo.

The amount of water supplied from the Tone River is about 6,500,000 m^3 per day. The population using Tone water is about 12,000,000. About 250,000 ha of land are irrigated in the Tone River basin. There are about 4,600 water intake facilities, and water rights for agricultural use total 1,320 m^3/s.

5.2 Map of Water Resource Systems



5.3 List of Major Water Resources Facilities

Major Reservoirs

Name of river	Name of dam (reservoir)	Catchment area [km^2]	Gross capacity [$10^6 m^3$]	Effective capacity [$10^6 m^3$]	Purposes[1)]	Year of completion
Tone	**Yagisawa**	167.4	204.3	175.8	F, A, P, W	1966
Tone	**Fujiwara**	401.0	52.5	35.9	F, A, P	1957
Naramata (Tone)	**Naramata**	60.1	90.0	85.0	F, A, W	1991
Akatani (Tone)	**Aimata**	110.8	110.8	20.0	F, A, P	1958
Katashina (Tone)	**Sonohara**	493.9	493.9	14.1	F, A, P	1965
Kanna (Tone)	**Shimokubo**	3229	130.0	120.0	F, A, P, W, I	1966
Kinu	**Ikari**	271.2	55.0	46.0	F, A, P	1956
Kinu	**Kawamata**	179.4	87.6	73.1	F, A, P	1965
Kinu	**Kawaji**	323.6	83.0	76.0	F, A, W, I	1983
Watarase	**Kusaki**	254.0	60.5	50.5	F, A, P, W, I	1976

Major Interbasin Transfer

Name of transfer line		Name of rivers and places connected: From	To	Length [km]	Maximum capacity [m^3/s]	Purpose[1)]	Year of completion
Tone Diversion	**Musashi Canal**	Tone-gawa	Ara-kawa	14.52	50.0	I, W	1968
	Saitama Canal	Tone-gawa	(Agricultural field)	16.68	34.0	A	1968
	Minumadai Canal	Tone-gawa	(Agricultural field)	102.9	43.4	A, W	1968
North-Chiba Water Conveyance Channel		Tone-gawa	Edo-gawa	28.5	40.0	F, W, N	1995

1) A: Agricultural use F: Flood control I: Industrial use N: Maintenance of normal flows P: Hydro-power
W: Municipal water supply

5.4 Major Floods and Droughts

Major Floods at Yattajima and Kurihashi

Date	Peak discharge at Yattajima [m^3/s]	Peak discharge at Kurihashi [m^3/s]	Rainfall [mm] Duration	Meteorological cause	Dead and missing	Major damages**
1947.9	17,000	-	300.5*	Typhoon “Catherine”	104 15	IAF: 121,762 IBF: 45,902
1948.9	-	6,640	203.0*	Typhoon “Ion”	36 7	IAF: 5,497 IBF: 2,861
1949.8	9,680	7,180	186.2*	Typhoon “Kitty”	83 6	IAF: 27,338 IBF: 19,508
1950.8	6,320	7,530	180.0*	Stationary Depression	8 14	IAF: 2,327 IBF: 3,848
1958.9	9,730	7,340	174.3*	Typhoon-22 “Kanogawa”	14 14	IAF: 970 IBF: 19,908
1959.8	9,070	10,050	217*	Typhoon-7	14 2	IAF: 984 IBF: 2,591
1966.6	5,880	5,490	170.1*	Typhoon-4	53 2	IAF: 1,561 IBF: 18,815
1971.8	2,460	3,940	166.4*	Typhoon-20	-	N.A.
1972.9	4,380	7,020	199.2*	Typhoon-20	-	N.A.
1977.8	-	3,621	over 300 mm (22 days)	Continuous Rain	-	N.A.
1979.10	1,756	3,572	300 mm at Watarase area	Typhoon-20	-	N.A.
1981.8	7,367	8,174	300-500 mm in mountain area	Typhoon-15	-	IAF: 78 IBF: 20
1982.8	7,529	11,118	-	Typhoon-18	- -	IAF: 1
1982.10	8,007	11,606	-		-	IAF: 1,268 IBF: 408
1991.9	-	4,688	-	Typhoon-18	- -	N.A.
1998.9	9,770	10,430	-	Typhoon-5	-	Inundated Area 182 ha

* Whole Tone basin, three day total precipitation.
** IAF: Inundation above floor, IBF: Inundation below floor in number of houses.

Major Droughts

Period	Affected areas	Major damages and counteractions
1964.5 - 1964.7	Kanto district	So called Olympic drought
1987.6 - 1987.8	Kanto district	Maximum cut ratio 30%
1994.7 - 1994.9	Kanto district	Maximum cut ratio 30%
1995.8 - 1995.9	Kanto district	Maximum cut ratio 30%

5.5 River Water Quality

River Water Quality[1)] at Kurihashi in 2000

Date	1 Jan	1 Feb	1 Mar	18 Apr	30 May	21 Jun	25 Jul	24 Aug	5 Sep	11 Oct	7 Nov	7 Dec
pH	7.6	7.6	7.5	7.3	7.2	7.4	7.5	7.3	7.4	7.5	7.5	7.5
BOD [mg/l]	2.6	2.4	2.7	1.4	0.6	1.6	1.4	2.5	1.1	0.9	1.1	3.1
DO [mg/l]	11.8	12.5	12.2	10.7	9.6	8.0	7.7	6.6	7.6	8.2	8.1	11.0
SS [mg/l]	5	9	7	10	17	17	27	100	21	9	15	8
Coliform group[2)] [$x10^3$MPN/100ml]	1.7	0.2	0.5	0.2	0.5	3.3	2.8	23.0	4.9	13.0	0.0	3.3
Discharge[3)] [m^3/s]	90.40	86.07	82.11	125.82	245.53	121.58	161.1	229.29	132.5	223.5	212.6	109.5

River Water Quality[1)] at Fukawa in 2000

Date	1 Jan	1 Feb	1 Mar	18 Apr	30 May	21 Jun	25 Jul	24 Aug	5 Sep	11 Oct	7 Nov	7 Dec
pH	7.6	7.5	7.8	7.4	7.4	7.5	7.9	7.7	7.7	7.5	7.5	7.6
BOD [mg/l]	2.4	2.3	3.1	2.3	1.4	1.9	2.0	1.9	1.4	0.5	1.1	0.9
DO [mg/l]	6.1	11.9	12.4	10.1	8.4	7.6	8.2	8.4	8.1	8.7	9.3	11.5
SS [mg/l]	4	8	6	13	12	16	12	13	23	14.5	11.5	7
Coliform group[2)] [$x10^3$MPN/100ml]	1.1	1.3	2.3	4.9	7.9	7.0	4.9	11.0	1.2	7.9	7.0	1.3
Discharge[3)] [m^3/s]	122.8	73.6	93.8	84.5	195.6	85.2	161.0	196.1	131.2	294.7	242.1	151.6

1) Observed once a month on a dry day normally several days after rainfall.
2) Measurement method: BGLB (brilliant green lactose bile) culture MPN (most probable number) method.
3) Discharge on the water quality observation date.

6. Socio-cultural Characteristics

The sea surface level is estimated to have fallen by over 100 m at the last glacial maximum some 20,000 years ago. The sea surface then started to rise in the inter-glacial stage, and about 5,000 years ago, reached a level several metres higher than the present level. At that time, the Kanto plain was a bay. When the sea level was falling, the ancient river course of the Tone was created. About 1,000 years ago the Tone River flowed to Tokyo bay, but about 300 years ago the course was diverted to the Pacific Ocean by the Tokugawa Shogunate.

The “Eastward Transfer of the Tone River” project was begun by Ieyasu Tokugawa, the first Shogun of the Tokugawa Shogunate in the Edo era. The purposes of the project were to protect the capital of Edo (the present day Tokyo) from floods, and to develop agriculture in the middle reaches of the Tone River. The project also provided the capital with a defensive barrier against attack by the kingdom of northern Japan.

The first western style flood control scheme was introduced in 1897. The design flood flow was set at 3,750 m^3/s at Kurihashi. In the severe flood of 1910, the estimated peak flow was about 7,000 m^3/s at Kurihashi, about twice the size of the design flood. This event led to a revision of the flood control scheme in the Tone River. However, since then the design flood flow has had to be revised several times because of floods that have exceeded the previous design values.

Edo, the capital of Tokugawa Shogunate, was renamed to Tokyo in the Meiji era, and continued to grow as the capital of Japan. The Tone River basin is located upstream of the Tokyo Metropolitan area, and rapid changes in land use have led to the need for repeated revisions of the design flood flow.

After the serious flooding caused by Typhoon Catherine in 1947, the Tone River has not experienced any breach of its embankments in spite of several major rainfall events. The Kanto Regional Development Bureau, Ministry of Land, Infrastructure, and Transport, has a responsibility for river management and continues to maintain this valuable water resource, to prevent flood disasters, and to preserve the nature and environment of the Tone River.

7. References, Databooks and Bibliography

Geological Survey of Japan (ed.) (1995): Geological Map of Japan 1:1,000,000, 3rd Edition, CD-ROM Version. Digital Geoscience Map G-1, Geological Survey of Japan.

Japan Meteorological Agency (2001): Japan Climatological Chart, 320 pp. (in Japanese)

Kanto Regional Construction Bureau, Ministry of Construction (1999): Catalogue of Hydrological Stations, 165 pp. (in Japanese)

Kanto Regional Construction Bureau (1993): TONEGAWA−Flood Control and Water Resources−. Kokudochousa-kai, 195 pp. (in Japanese)

Kanto Regional Construction Bureau (1987): Tonegawa hyakunenshi (100 year's history of the Tone River), Ministry of Construction, 2303 pp. (in Japanese)

Kanto Regional Development Bureau, MLIT (2001): Flood Control and Water Resources in the Tone River, Japan River Association, 14 pp. (in Japanese)

Kinu River Dam Control Office, Kanto Regional Construction Bureau, Outline of Dams in Kinu River Basin. 35 pp. (in Japanese)

Lower Tone River Office, Edo-gawa River Office, Kanto Regional Construction Bureau, Ministry of Construction (2000): North-Chiba Water Conveyance Channel, 26 pp. (in Japanese)

Lower Tone River Office, Kanto Regional Construction Bureau, Ministry of Construction: Tone River −Lower Basin of the Tone River, 22 pp.

River Bureau (1947-2000): Ryuryo nenpyo (Streamflow yearbook).

Tone River Dam Control Office, Kanto Regional Development Bureau, MLIT (2001): Outline of Dams in Tone River Basin. (in Japanese)

Tomiyama, Kazuko (1974): Water, Green, and Soil. Chuko-Shinsho, (in Japanese)

Upper Tone River Office, Kanto Regional Development Bereau, MLIT (2001): Encyclopedia of TONEGAWA, http://www.tonejo.go.jp/jiten/ (Japanese contents)

Upper Tone River Office, Kanto Regional Construction Bureau: Tone River, 29 pp. (in Japanese)

Water Resources Development Public Corporation: Outline of Tone Water Canal. (in Japanese)