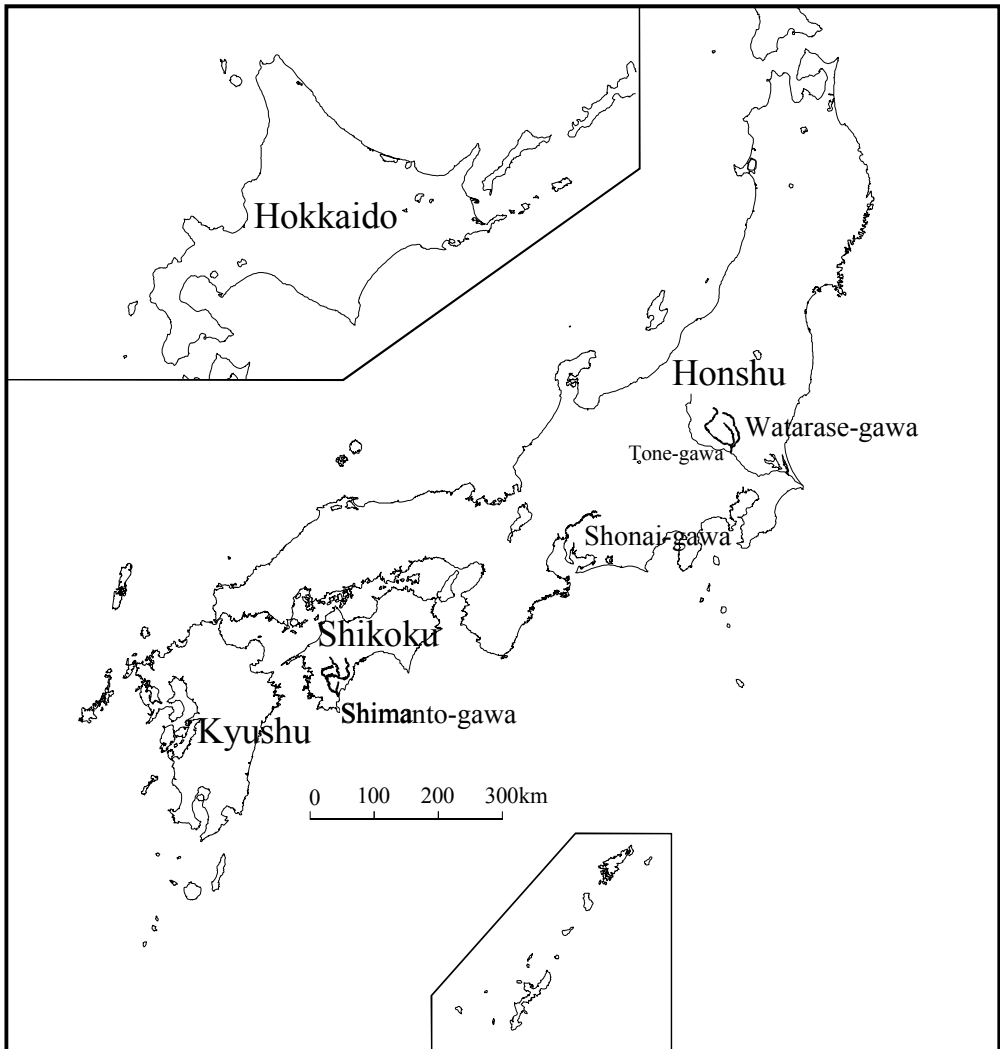


# Japan

**Japan-7: Shimanto-gawa**

**Japan-8: Shonai-gawa**

**Japan-9: Watarase-gawa**



## Introduction

The three rivers presented in this volume were selected on the basis of their unique features. Shimanto-gawa in Shikoku Island is considered as one of the few rivers in Japan that still preserves the original nature of the basin to a large extent. There are no major dams constructed along the main stream or its branches. A major part of the basin consists of forests, agricultural and urbanized lands, leaving the ecological nature of the catchment barely disturbed. In this basin, which has rich seasonal vegetation changes, the traditional pattern of human coexistence with fish and wild life preserves the river regime under seasonal changes. Shonai-gawa in the mid-western Honshu Island is one of the typical rivers under ever increasing urban influence. Located to the north of Nagoya city which is one of the largest urban areas in Japan, the basin receives growing population and industrialization as a transform from traditional agricultural activities. An integrated river basin management program, which includes pollution control, urban flood management, popular access to riversides, etc., is being implemented on a trial basis in this basin. In particular, the problem of pollution control, monitoring and management is currently receiving nationwide attention. Watarase-gawa, which is a major branch of Tone-gawa, the largest river in Central Honshu Island, is a river that has experienced a tragic copper mining pollution problem from the latter part of the 19th century to the early part of the 20th century. The sulphur dioxide from the Ashio Copper Mine smelteries located near the headwaters of the river destroyed nearly all the vegetation around the area and affected the downstream eventually forcing a whole village to be relocated. The mines were closed in early 70's and extensive forest rehabilitation started at that time. Finally, nearly all forest recovered only recently. During this whole process, some major changes of the hydrological regime were experienced.

## Acknowledgements

An editorial committee chaired by Kuniyoshi Takeuchi was formed within the IHP Working Group, the Japan National Committee for the IHP and took the responsibility of the preparation of the manuscripts. They were prepared by the following members:

**Shimanto-gawa:** Michio Hashino, Tokushima University; Nobuyuki Wakabayashi, Shikoku Regional Construction Bureau, Ministry of Construction,

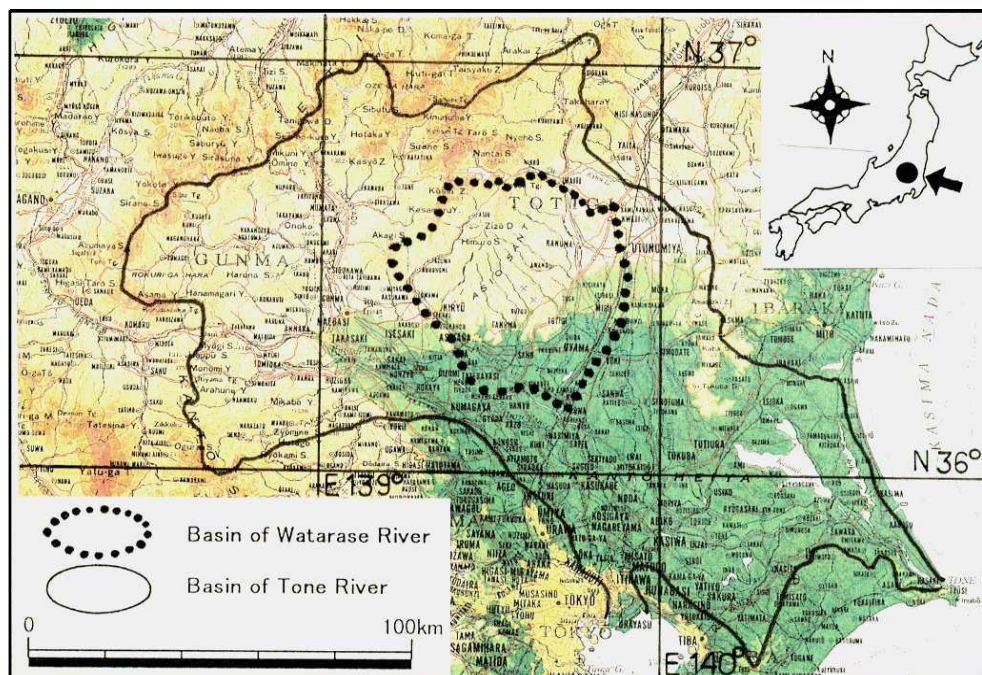
**Shonai-gawa:** Kaoru Takara, Kyoto University; Kazuhide Sasaki and Makoto Matsubara, Shonai-gawa Construction Office, Ministry of Construction,

**Watarase-gawa:** Shigeki Kobatake, Gunma University; Tadashi Akabane and Masahiro Mukai, Watarase-gawa Construction Office, Ministry of Construction.

The editorial committee is especially grateful to the member, Takeo Kinoshita, Suimon Kankyo, Co. Ltd. for his extensive review of the draft.

## Watarase-gawa

### Map of River



### Table of Basic Data

|   |   |                            |
|---|---|----------------------------|
| <b>Name:</b> Watarase-gawa  |   | <b>Serial No.:</b> Japan-9 |
| <b>Location:</b> Central Honshu, Japan  | N 36° 09' ~ 36° 44'                                 | E 139° 12' ~ 139° 52'      |
| <b>Area:</b> 2 602 km <sup>2</sup>  | <b>Length of main stream:</b> 108 km                |                            |
| <b>Origin:</b> Mt. Sukai(2 144 m)   | <b>Highest point:</b> Mt. Sukai (2 144 m)           |                            |
| <b>Outlet:</b> Tone River   | <b>Lowest point:</b> Confluence to the Tone (9.5 m) |                            |
| <b>Main geological features :</b> Sedimentary rocks : Cenozoic era, Sand and Gravel, Volcanic ash, Paleozoic era, Slate, Sandstone, Chert, Plutonic rocks : Granite |   |                            |
| <b>Main tributaries:</b> Omoi River (872 km <sup>2</sup> ), Uzuma River (218 km <sup>2</sup> ), Hata River (178 km <sup>2</sup> )                                   |   |                            |
| <b>Main lakes:</b> None   |   |                            |
| <b>Main reservoirs:</b> Kusaki reservoir (60.5×10 <sup>6</sup> m <sup>3</sup> , 1977), Watarase-Daiichi reservoir(26.4×10 <sup>6</sup> m <sup>3</sup> , 1991)       |   |                            |
| <b>Mean annual precipitation:</b> 1 425 mm (1967~1996) (basin average)  |   |                            |
| <b>Mean annual runoff:</b> 18.75 m <sup>3</sup> /s at Takatsudo (472 km <sup>2</sup> ) (1960~1996)  |   |                            |
| <b>Population:</b> 1 292 720 (1990)   | <b>Main cities:</b> Kiryu, Ashikaga                 |                            |
| <b>Land use:</b> Forest (66.1 %), Paddy field (13.0 %), other Agriculture (8.1 %), Water Surface (4.6 %), Urban (8.2 %)   |   |                            |

## 1. General Description

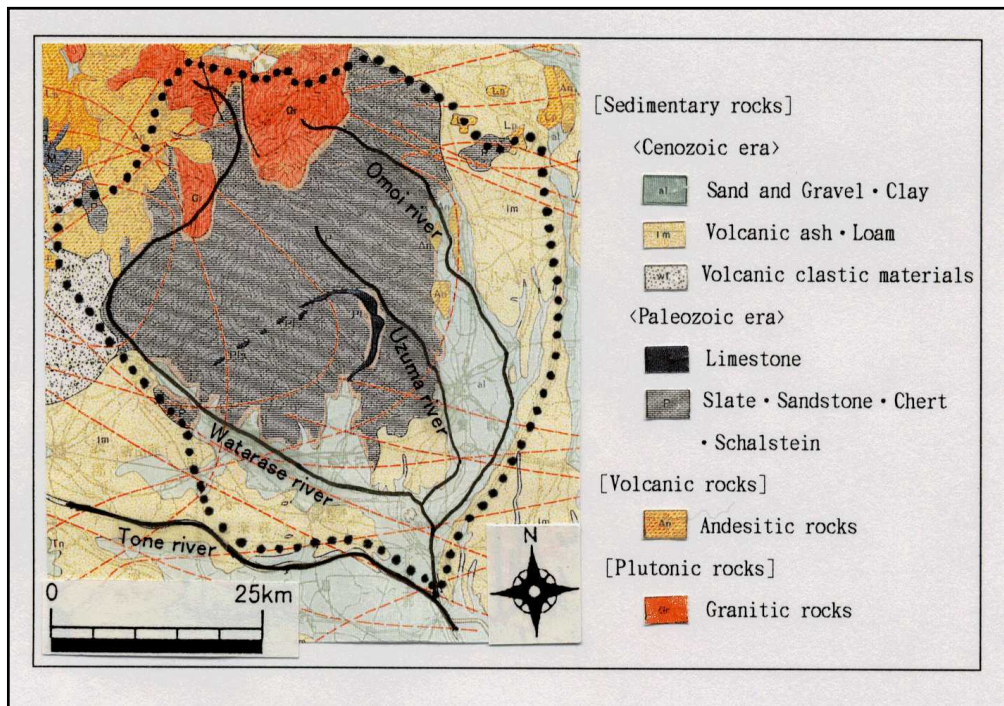
The Watarase-gawa is the largest tributary of the Tone River that forms the largest river basin in Japan. It is located in the central part of Honshu Island. The upper basin of the Watarase-gawa was devastated by copper mining and refineries during the period 1880~1950. Erosion control or Sabo works have been carried out under the supervision of the national and prefectural governments to preserve blighted areas and prevent soil related disasters. In recent years, the blighted areas have been regaining their vegetation. In the downstream areas, deposits of polluted sediments transported by flash floods raised social problems on occasions.

The Watarase-gawa is 108 km long and drains an area of 2 602 km<sup>2</sup>. Originating from Mt. Sukai (2 144 m), it first flows southward through narrow valleys to the Oomama alluvial fan located at the northwest edge of the Kanto-Plain, and then turns eastward to the confluence with the Tone River. About 66 % of the basin is mountainous while the rest is plain.

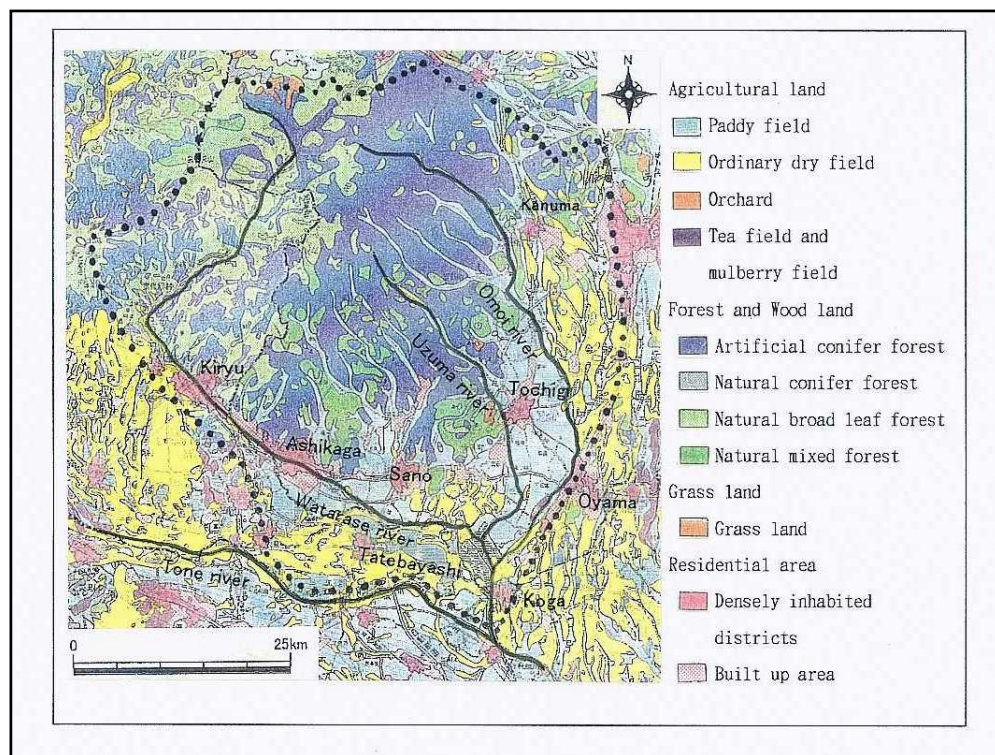
The catchment receives an average annual precipitation of approximately 1 400 mm (basin average). The mean annual discharge at Takatsudo (472 km<sup>2</sup>) during the period from 1960 to 1996 has been 18.75 m<sup>3</sup>/s. There are two multi-purpose reservoirs on the main channel and one small size reservoir on a tributary. Watarase Daiichi Reservoir, one of the two reservoirs on the main channel, was constructed by excavating about 4.5 km<sup>2</sup> area of the Watarase Retarding Basin located near the confluence. The population in the basin in 1990 was about 1 300 000.

## 2. Geographical Information

### 2.1. Geological Map



## 2.2. Land Use Map



## 2.3. Characteristics of River and Main Tributaries

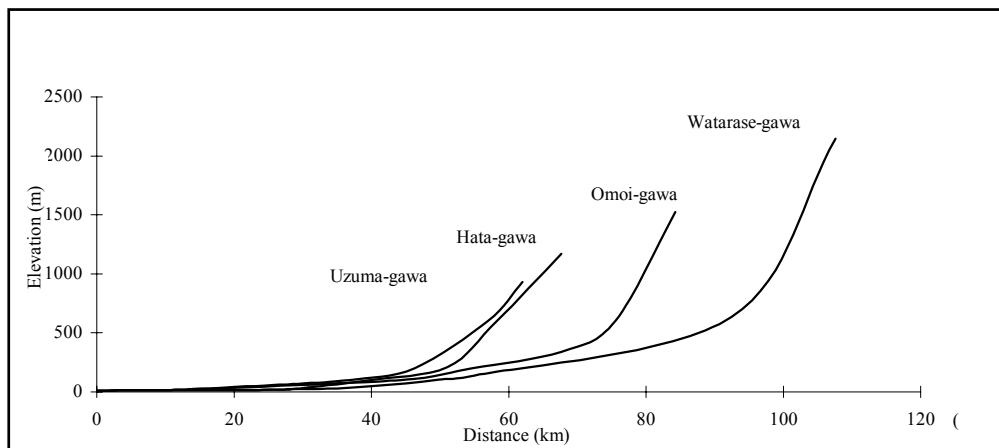
| No. | Name of river                   | Length [km]<br>Catchment area [km <sup>2</sup> ] | Highest peak [m]<br>Lowest point [m] <sup>2)</sup> | Cities<br>Population (1990)       | Land use <sup>3)</sup><br>[%] (1995)                          |
|-----|---------------------------------|--|--|-----------------------------------|---|
| 1   | <b>Watarase</b><br>(Main river) | 108<br>1 334                                     | Mt.Sukai 2 144<br>Confluence 11                    | Kiryu, Asikaga<br>Koga<br>687 064 | F(66.1 %)<br>P(13.0 %)<br>A( 8.1 %)<br>L( 4.6 %)<br>U( 8.2 %) |
| 2   | <b>Hata</b><br>(Tributary)      | 41<br>178  | Mt.Kumataka 1 169<br>Confluence 20                 | 39 962                            |   |
| 3   | <b>Uzuma</b><br>(Tributary)     | 52 <sup>1)</sup><br>218                          | Mt.Ode 933<br>Confluence 12                        | Tochigi<br>119 459                |   |
| 4   | <b>Omoi</b><br>(Tributary)      | 78<br>872  | Mt.Yuhi-dake 1 526<br>Confluence 11                | Kanuma, Oyama<br>446 235          |   |

<sup>1)</sup>The data is of the Nagano River that is a tributary of Uzuma River, because Nagano River is longer than Uzuma River.

<sup>2)</sup>The lowest point indicates the mean riverbed level at the confluence at the present condition.

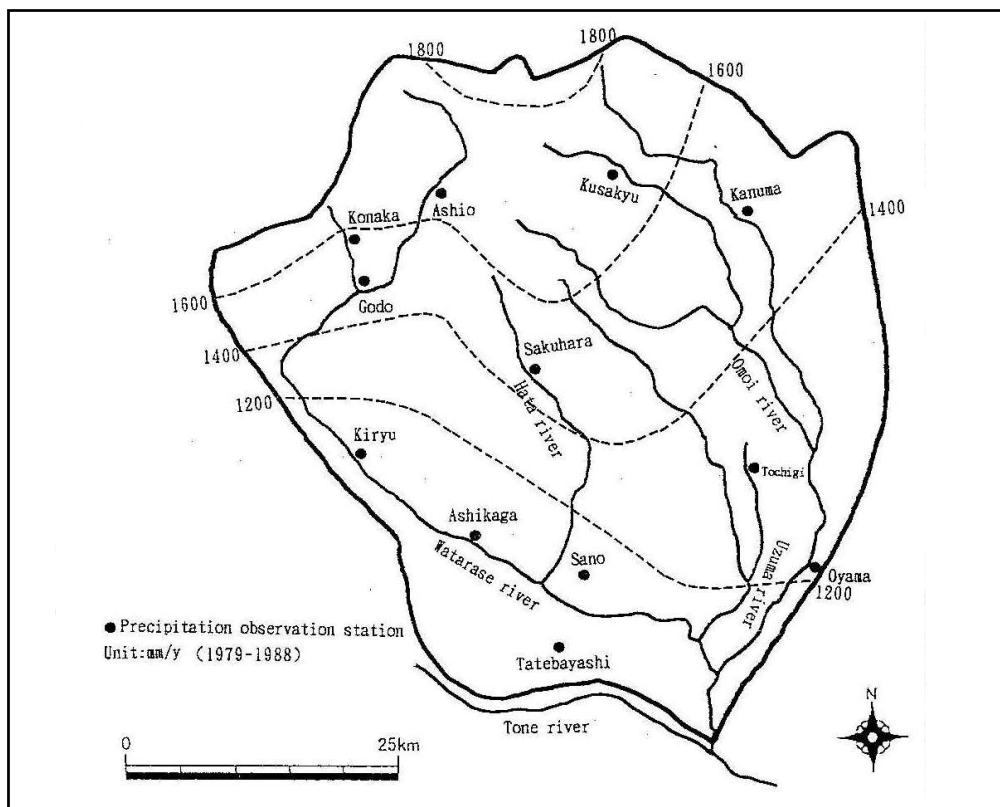
<sup>3)</sup> F : Forest P : Paddy field A : Other agricultural field (vegetable, grass) L : Lake, River, Marsh U : Urban

## 2.4. Longitudinal Profiles



## 3. Climatological Information

### 3.1. Annual Isohyetal Map and Observation Stations



### 3.2. List of Meteorological Observation Stations

| No.         | Station                | Elevation [m] | Location                      | Observation period | Mean annual precipitation [mm] | Observation items <sup>1)</sup> |
|-------------|------------------------|---------------|-------------------------------|--------------------|--------------------------------|---------------------------------|
| 30404<br>*  | Ashio                  | 634           | N 36° 38'09"<br>E 139° 26'58" | 1942~present       | 1 712<br>1942~1996             | P                               |
| 30405<br>*  | Godō                   | 328           | N 36° 31'01"<br>E 139° 20'20" | 1959~present       | 1 466<br>1963~1996             | P                               |
| 30409<br>*  | Ashikaga               | 42            | N 36° 19'54"<br>E 139° 26'56" | 1953~present       | 1 166<br>1953~1996             | P                               |
| 30421<br>*  | Konaka                 | 514           | N 36° 33'18"<br>E 139° 20'16" | 1957~present       | 1 515<br>1960~1996             | P                               |
| 30427<br>*  | Sakuhara               | 210           | N 36° 28'46"<br>E 139° 30'03" | 1959~present       | 1 544<br>1960~1996             | P                               |
| 30429<br>*  | Kusagyu                | 340           | N 36° 38'13"<br>E 139° 36'34" | 1922~present       | 1 782<br>1924~1996             | P                               |
| 42266<br>** | Kiryu                  | 88            | N 36° 22'09"<br>E 139° 20'09" | 1955~present       | 1 095<br>1955~1996             | DS, P                           |
| 42251<br>** | Maebashi <sup>2)</sup> | 112           | N 36° 24'01"<br>E 139° 03'09" | 1896~present       | 1 130<br>1961~1990             | DS, P, SR                       |

\*: Serial number used by River Bureau, Ministry of Construction.

\*\* : Serial number used by Meteorological Observatory, Japan Meteorological Agency.

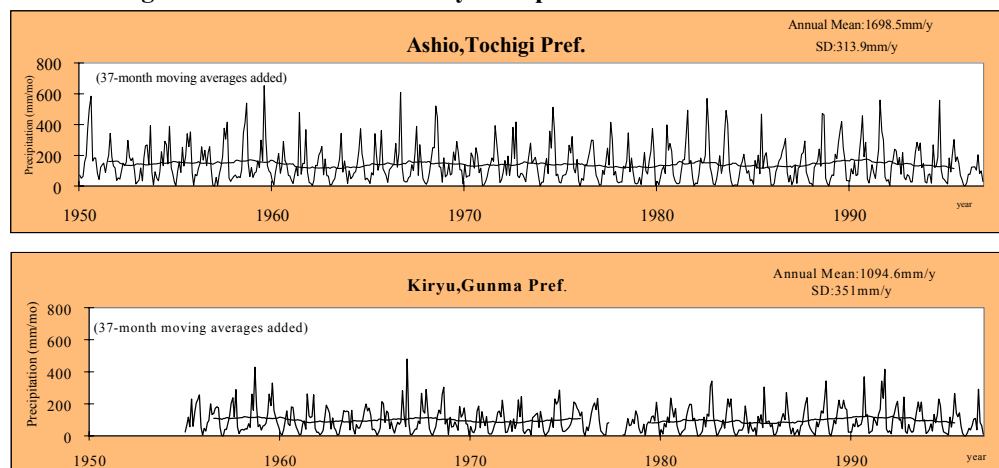
1) P : Precipitation, DS: Duration of sunshine, SR: Solar radiation.

2) Maebashi is located outside the Watarase basin and about 24 km west from Kiryu

### 3.3. Monthly Climate Data

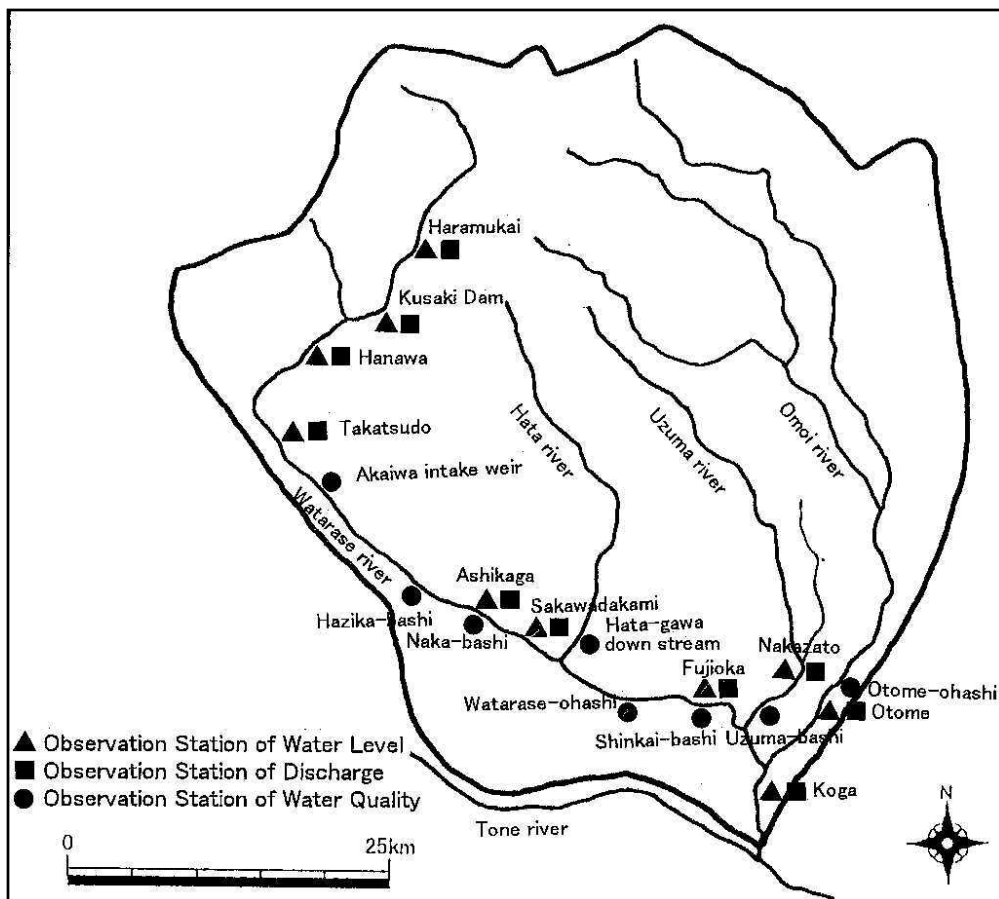
| Observation item                       | Observation station | Jan   | Feb   | Mar   | Apr   | May   | Jun   | Jul   | Aug   | Sep   | Oct   | Nov   | Dec   | Annual  | Period for the mean |
|--|---------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------|---------------------|
| Temperature [°C]                       | Kiryu               | 3.1   | 3.8   | 7.0   | 13.0  | 17.7  | 21.2  | 24.6  | 26.3  | 21.9  | 16.0  | 10.4  | 5.4   | 14.2    | 1965~1996           |
| Precipitation [mm]                     | Kiryu               | 23.2  | 36.4  | 56.7  | 77.2  | 109.1 | 159.0 | 153.8 | 163.4 | 195.7 | 121.2 | 51.2  | 25.4  | 1 094.6 | 1955~1996           |
| Solar radiation [MJ/m <sup>2</sup> /d] | Maebashi            | 9.5   | 11.4  | 14.1  | 15.7  | 17.2  | 13.5  | 13.6  | 14.3  | 10.7  | 10.6  | 8.8   | 8.4   | 12.3    | 1961~1990           |
| Duration of sunshine [hr]              | Kiryu               | 217.8 | 201.5 | 219.4 | 203.9 | 213.5 | 150.8 | 156.4 | 197.7 | 145.2 | 175.7 | 184.1 | 209.6 | 2 149.0 | 1965~1996           |

### 3.4. Long-term Variation of Monthly Precipitation Series



## 4. Hydrological Information

### 4.1. Map of Streamflow Observation Stations



#### 4.2. List of Hydrological Observation Stations

| No.*  | Station      | Location   | Catchment area (A) [km <sup>2</sup> ] | Observation period | Observation items <sup>1)</sup> (Frequency) |
|-------|--------------|--|---------------------------------------|--------------------|---|
| 30424 | Takatsudo    | 52.2 km from the confluence of the Tone river      | 472.0                                 | 1960~present       | H, Q(h)                                     |
| 30427 | Fujioka      | 12.9 km from the confluence of the Tone river      | 1 209.5                               | 1980~present       | H, Q(h)                                     |
| 30438 | Nakazato     | 4.1 km from the confluence of the Watarase river   | 205.4                                 | 1978~present       | H, Q(h)                                     |
| 30439 | Otome        | 13.13 km from the confluence of the Watarase river | 760.0                                 | 1938~present       | H, Q(h)                                     |
| 30440 | Sakawadakami | 28.56 km from the confluence of the Tone river     | 748.4                                 | 1980~present       | H, Q(h)                                     |

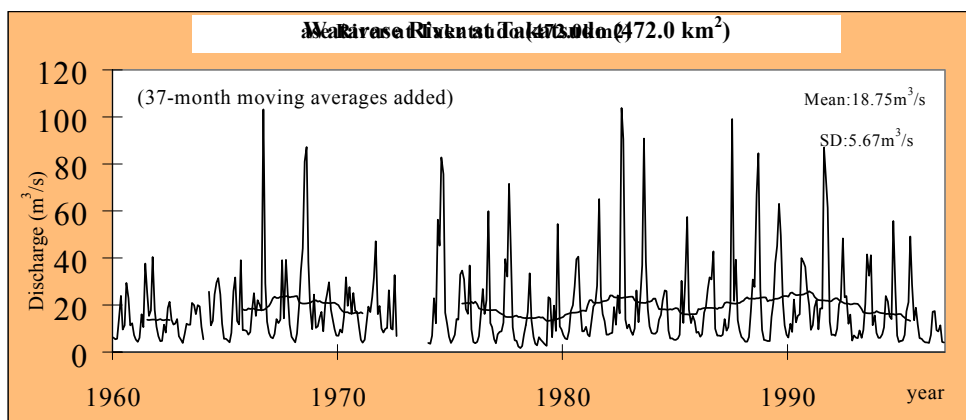
| No.*  | $\bar{Q}$ <sup>2)</sup> [m <sup>3</sup> /s] | $Q_{\max}$ <sup>3)</sup> [m <sup>3</sup> /s] | $\bar{Q}_{\max}$ <sup>4)</sup> [m <sup>3</sup> /s] | $\bar{Q}_{\min}$ <sup>5)</sup> [m <sup>3</sup> /s] | $\bar{Q} / A$ [m <sup>3</sup> /s/100km <sup>2</sup> ] | $Q_{\max} / A$ [m <sup>3</sup> /s/100km <sup>2</sup> ] | Period of statistics |
|-------|---|--|--|--|---|--|----------------------|
| 30424 | 18.75                                       | 3 511  | 742  | 3.14   | 3.97  | 744  | 1960~1995            |
| 30427 | 37.31                                       | 1 915  | 909  | 3.65   | 3.08  | 158  | 1980~1995            |
| 30438 | 6.75  | 421  | 163  | 0.86   | 3.29  | 205  | 1978~1996            |
| 30439 | 30.15                                       | 2 151  | 747  | 4.83   | 3.97  | 283  | 1951~1996            |
| 30440 | 21.55                                       | 1 821  | 904  | 2.98   | 2.88  | 243  | 1980~1995            |

\*:Serial number used by River Bureau, Ministry of Construction

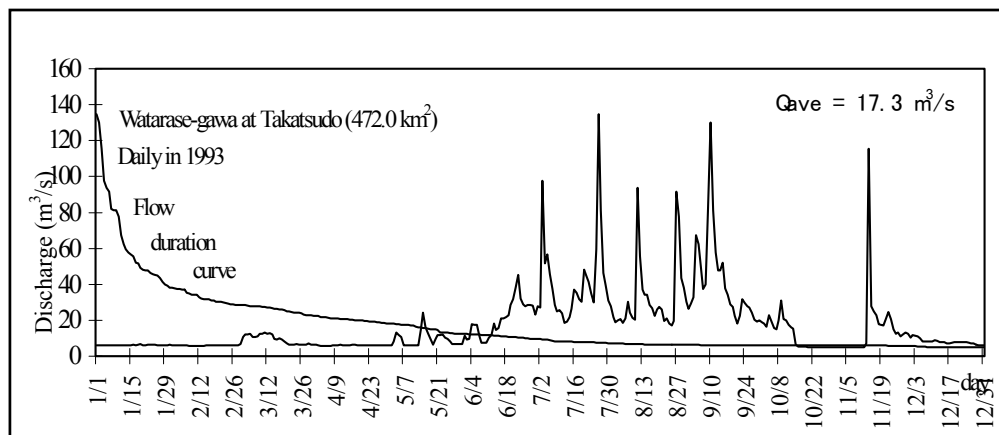
1) H : Water level in recording chart, Q(h):Discharge, hourly; 2) Mean annual discharge; 3) Maximum discharge;

4) Mean annual maximum discharge; 5) Mean annual minimum discharge

#### 4.3. Long-term Variation of Monthly Discharge



#### 4.4. Annual Pattern of Discharge



#### 4.5. Unique Hydrological Features

Before the 17<sup>th</sup> century, the watercourses of the Tone and Watarase Rivers did not merge downstream as they do today, but travelled downstream taking their separate courses to Tokyo Bay. As a result of the river improvement works called “Eastward transfer of the Tone River” carried out during the 17<sup>th</sup> century, the Tone River channel changed eastward to directly discharge into the Pacific Ocean as it does today. From that time, Watarase-gawa has been a tributary of Tone river.

The mountain slopes facing the southeast in this basin experience heavy rainfall caused by the intrusion of damp south-easterly winds due to typhoons. In 1947, Typhoon Catherine brought about a disastrous flood that surpassed all previous records. Some 709 persons were killed or lost in Watarase basin, mainly in the Kiryu and Ashikaga districts, as a result of embankment failures. The rainfall amounts observed at Ashio and Kiryu during September 13~15 were 386 mm and 370 mm respectively, while a maximum value of 470 mm in the Watarase basin was observed at Mt. Akagi located 20 km northeast of Kiryu.

The peak discharge of 4 600 m<sup>3</sup>/s at the control point Takatsudo, which is used for flood control planning in the Watarase-gawa before regulation, is based on the 1947 flood. Of this flow, 1 100 m<sup>3</sup>/s is to be regulated by Kusaki Dam and 3 500 m<sup>3</sup>/s is discharged through the river channel. At the confluence with Tone River, the design flood is 9 400 m<sup>3</sup>/s. The Watarase Retarding Basin located near the confluence has an area of about 33 km<sup>2</sup> and a capacity of about 200 million m<sup>3</sup>. Being the largest retarding basin in Japan, it regulates the design flood discharge of 9 400 m<sup>3</sup>/s (Watarase River 4 500 m<sup>3</sup>/s, Omoi river 3 700 m<sup>3</sup>/s, Uzuma River 1 200 m<sup>3</sup>/s) so that the peak discharge of Tone River is not exceeded.

Ashio Sabo Dam located in the upstream of Watarase-gawa has a catchment area of 54 km<sup>2</sup> of which 44 % was barren mountains during the golden age of copper production. The mine was closed in 1973 after the production of some 700 000 tons of copper. The once barren land has now been rehabilitated after intensive erosion control or Sabo works. In recent years, the peak runoff observed at Kusaki Dam is smaller than what it was some 20 years ago.

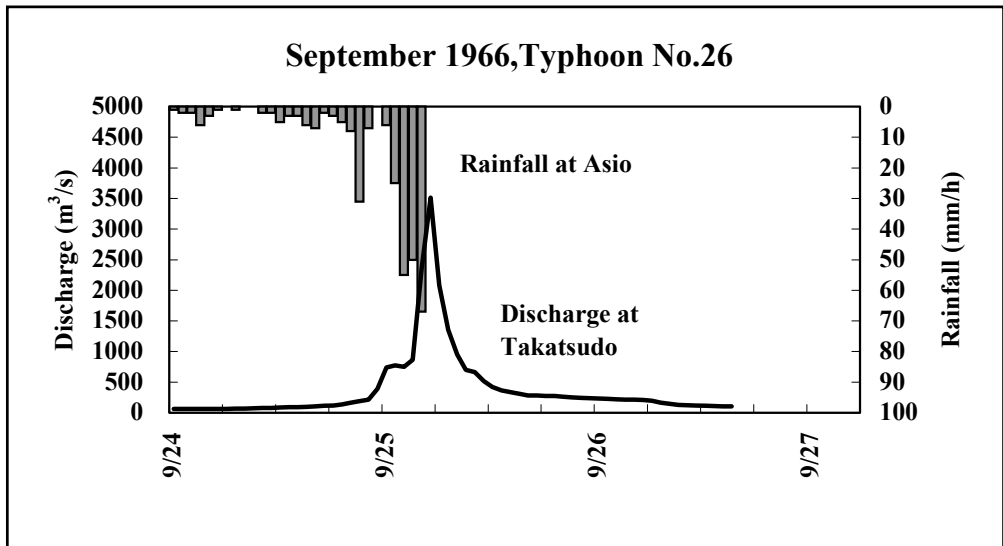
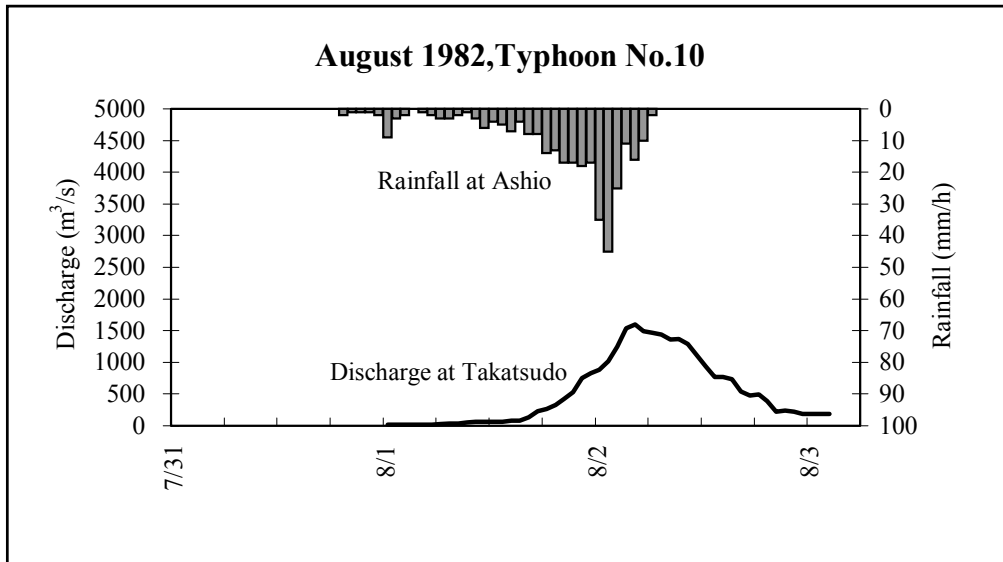
## 4.6. Annual Maximum and Minimum Discharges

At Takatsudo [472 km<sup>2</sup>]

| Year | Maximum <sup>1)</sup> |                     | Minimum <sup>2)</sup> |                     | Year | Maximum <sup>1)</sup> |                     | Minimum <sup>2)</sup> |                     |
|------|-----------------------|---------------------|-----------------------|---------------------|------|-----------------------|---------------------|-----------------------|---------------------|
|      | Date                  | [m <sup>3</sup> /s] | Date                  | [m <sup>3</sup> /s] |      | Date                  | [m <sup>3</sup> /s] | Date                  | [m <sup>3</sup> /s] |
| 1960 | 8/11                  | 205.3               | 3/2                   | 3.7                 | 1978 | 7/11                  | 520.8               | 2/6~8,<br>19~24       | 1.3                 |
| 1961 | 6/28                  | 977                 | 2/18                  | 3.5                 | 1979 | 10/19                 | 1 171.2             | 4/27                  | 1.9                 |
| 1962 | 7/14                  | 82.7                | 2/8                   | 2.3                 | 1980 | 9/11                  | 308.8               | 3/6,13,<br>14         | 4.5                 |
| 1963 | 10/30                 | 136.9               | 2/6                   | 2.3                 | 1981 | 8/23                  | 1 173.4             | 3/3                   | 5.5                 |
| 1964 | 7/9                   | 171.8               | 12/9                  | 0.4                 | 1982 | 8/2                   | 1 596.7             | 1/2                   | 6.2                 |
| 1965 | 9/18                  | 850.6               | 2/1                   | 0.7                 | 1983 | 8/17                  | 1 093.7             | 6/12                  | 6.5                 |
| 1966 | 9/25                  | 3 511.3             | 8/11                  | 1                   | 1984 | 6/29                  | 81.3                | 9/24                  | 3.4                 |
| 1967 | 7/10                  | 162.5               | 2/4~<br>2/21          | 2.2                 | 1985 | 7/1                   | 1 279.1             | 1/16,17               | 4.2                 |
| 1968 | 7/29                  | 728.7               | 2/22                  | 0.7                 | 1986 | 9/3                   | 629.5               | 2/6                   | 4.4                 |
| 1969 | 6/26                  | 657.7               | 12/31                 | 4.6                 | 1987 | 9/11                  | 500.4               | 5/7                   | 4.9                 |
| 1970 | 11/20                 | 188.7               | 1/22                  | 0.7                 | 1988 | 8/12                  | 421.7               | 1/31                  | 3.9                 |
| 1971 | 8/31                  | 518.8               | 2/5                   | 1.6                 | 1989 | 8/28                  | 812.9               | 3/18~<br>24,4/4~<br>6 | 4.1                 |
| 1972 |                       |                     |                       |                     | 1990 | 8/10                  | 1260.7              | 3/29                  | 4.6                 |
| 1973 |                       |                     |                       |                     | 1991 | 8/21                  | 1325.7              | 5/21                  | 6.1                 |
| 1974 | 8/26                  | 1 407.3             | 1/20                  | 0.4                 | 1992 | 5/31                  | 291.9               | 11/4                  | 4.3                 |
| 1975 | 8/23                  | 285.3               | 1/16~ 25,<br>31,2/1~4 | 2.6                 | 1993 | 7/26                  | 378.9               | 10/20~<br>11/12       | 5.1                 |
| 1976 | 9/14                  | 437.8               | 4/6                   | 0.2                 | 1994 | 9/30                  | 850.9               | 12/3                  | 4.2                 |
| 1977 | 8/17                  | 1 032.3             | 12/20,<br>25          | 1                   | 1995 | 6/16                  | 191.2               | 1/9                   | 3.9                 |

1), 2) Instantaneous observation by recording chart

4.7. Hyetographs and Hydrographs of Major Floods



## 5. Water Resources

### 5.1. General Description

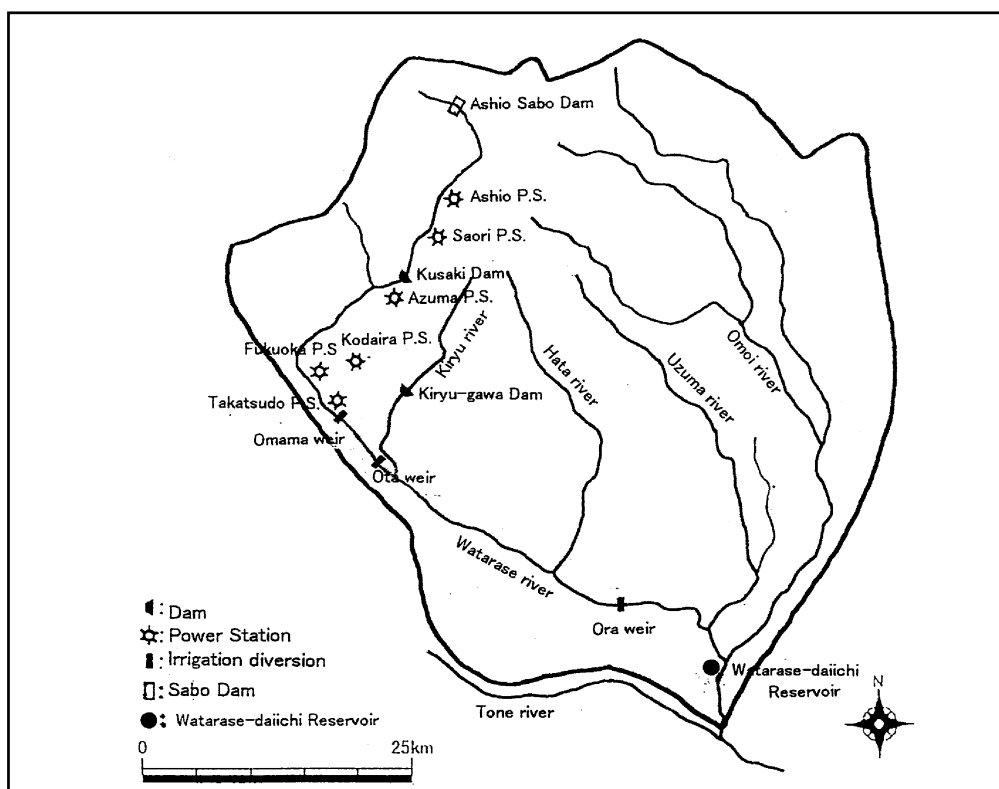
The water rights issued for each industry in Watarase Basin are shown in the following Table.

| Use                          | Municipal | Industrial | Agricultural | Electric power | Others | Total   |
|------------------------------|-----------|------------|--------------|----------------|--------|---------|
| Number                       | 9         | 2          | 19           | 7              | 1      | 38      |
| Quantity [m <sup>3</sup> /s] | 2.475     | 0.515      | 46.524       | 117.76         | 0.012  | 167.286 |

There are seven hydropower stations with a total capacity of about 90.6 MW. The headworks at Oomama, Oota and Oora provide the large intakes for paddy field irrigation.

There are two multi-purpose reservoirs, Kusaki Reservoir (60.5x10<sup>6</sup> m<sup>3</sup>) and Watarase Daiichi Reservoir (26.4x10<sup>6</sup> m<sup>3</sup>) on the main channel. The former is managed by the Water Resources Development Public Corporation and the latter is under national management. A relatively small size one Kiryu- Gawa Dam (12.3x10<sup>6</sup> m<sup>3</sup>) is on a tributary and this is under prefectural management. The Watarase Daiichi Reservoir was constructed by excavating an area of about 4.5 km<sup>2</sup> of Watarase Retarding Basin and was based on the Specified Multi-purpose Dam Act to accommodate growing water demand of metropolitan area.

### 5.2. Map of Water Resources Systems



### 5.3. List of Major Water Resources Facilities

#### Major Reservoirs

| Name of river | Name of dam (reservoir)        | Catchment area [km <sup>2</sup> ] | Gross capacity [10 <sup>6</sup> m <sup>3</sup> ] | Effective capacity [10 <sup>6</sup> m <sup>3</sup> ] | Purpose <sup>1)</sup> | Year of completion |
|---------------|--------------------------------|-----------------------------------|--|--|-----------------------|--------------------|
| Watarase      | Kusaki                         | 254                               | 60.5   | 50.5   | A, F, I, P, W         | 1977               |
| Watarase      | Watarase-daiichi <sup>2)</sup> | -                                 | 26.4   | 21.4   | F, I, N, W            | 1991               |
| Kiryu         | Kiryu-gawa                     | 42                                | 12.2   | 11.3   | F, N, W               | 1981               |

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

2) This reservoir was constructed by excavating an area of about 4.5km<sup>2</sup> in the Watarase Retarding Basin.

### 5.4. Major Floods and Droughts

#### Major Floods

| Date   | Stations Catchment area [ km <sup>2</sup> ] | Peak discharge [m <sup>3</sup> /s] | Rainfall [mm] Duration          | Meteorological cause | Dead and missing | Major damages (Districts affected)   |
|--------|---|------------------------------------|---------------------------------|----------------------|------------------|--|
| 1947.9 | Sakawada 748                                | 3 819                              | 386(Ashio) 370(Kiryu) 9/13~9/15 | Typhoon “Catherine”  | 709              | River bank broken; 4 475m<br>Houses destroyed; 2 070<br>Houses inundated; 31 779               |
| 1948.9 | Sakawada 748                                | 3 780                              | 300(Ashio) 136(Kiryu) 9/15~9/16 | Typhoon “Ion”        | N.A              | River bank broken; 200m<br>Houses destroyed; 3<br>Houses inundated; 1 161                      |
| 1949.8 | Sakawada 748                                | 3 650                              | 439(Ashio) 49(Kiryu) 8/30~9/1   | Typhoon “Kitty”      | 10               | River bank broken; 2 901m<br>Houses destroyed; 531<br>Houses inundated; 1 311                  |
| 1966.9 | Takatsudo 472                               | 3 511                              | 292(Ashio) 131(Kiryu) 9/24      | Typhoon No.26        | 0                | Houses destroyed or inundated above floor level; 26<br>Houses inundated below floor level; 426 |
| 1982.9 | Takatsudo Sakawada                          | 1 597<br>1 637                     | 222(Ashio) 249(Kiryu) 9/10~9/12 | Typhoon No.18        | 0                | Houses inundated; 137  |

## Major Droughts

| Period        | Precipitation (Kiryu )                          | Number of days of restricted water supply and maximum cut ratio(Kiryu city) |
|---------------|---|---|
| 1994.7~1994.9 | 1994.4~1994.9<br>378 mm (84.2 % <sup>1)</sup> ) | 59 days, 30 %   |
| 1996.1~1996.3 | 1995.11~1996.3<br>84 mm (43.5 % <sup>1)</sup> ) | 76 days, 10 %   |
| 1996.7~1996.9 | 1996.4~1996.8<br>355 mm (53.6 % <sup>1)</sup> ) | 41 days, 40 %   |

1)The ratio to the average precipitation (1955~1996) at Kiryu during the same duration

## 5.5. Groundwater and River Water Quality

### River Water Quality<sup>1)</sup>

#### At Hazika-bashi <sup>2)</sup> in 1993

| Date   | Jan 26                   | Feb 16                   | Mar 9                    | Apr 20                   | May 25                   | Jun 22                   | Jul 20                   | Aug 24                   | Sep 21                   | Oct 19                   | Nov 24                   | Dec 14                   |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| pH   | 7.5                      | 8.5                      | 8.3                      | 8.4                      | 8.5                      | 7.4                      | 7.3                      | 7.5                      | 7.4                      | 7.9                      | 7.5                      | 7.8                      |
| BOD [mg/l]                                     | 3.2                      | 2.8                      | 3.0                      | 2.5                      | 2.6                      | 1.2                      | 0.9                      | 0.9                      | 0.9                      | 1.1                      | 1.1                      | 1.3                      |
| COD <sub>Mn</sub> [mg/l]                       | 3.3                      | 5.0                      | 3.4                      | 4.4                      | 4.5                      | 4.0                      | 2.7                      | 2.6                      | 1.9                      | 3.1                      | 2.1                      | 2.8                      |
| SS [mg/l]                                      | 6                        | 5                        | 10                       | 4                        | 9                        | 24                       | 11                       | 3                        | 1                        | 2                        | 3                        | 2                        |
| Coliform group <sup>3)</sup><br>[MPN/100ml]    | 1.6 x<br>10 <sup>5</sup> | 9.4 x<br>10 <sup>2</sup> | 2.1 x<br>10 <sup>3</sup> | 4.9 x<br>10 <sup>3</sup> | 7.9 x<br>10 <sup>3</sup> | 4.9 x<br>10 <sup>4</sup> | 2.4 x<br>10 <sup>4</sup> | 1.3 x<br>10 <sup>4</sup> | 1.3 x<br>10 <sup>4</sup> | 7.9 x<br>10 <sup>3</sup> | 4.6 x<br>10 <sup>2</sup> | 2.6 x<br>10 <sup>3</sup> |
| Discharge <sup>4)</sup><br>[m <sup>3</sup> /s] | 9.20                     | 7.05                     | 14.50                    | 5.65                     | 6.82                     | 27.40                    | 56.40                    | 9.51                     | 12.00                    | 7.62                     | 15.40                    | 8.70                     |

1) Observed once a month.

2) Located near Ashikaga City 42.2km upstream from the confluence with the Tone River.

3) Measurement method: BGLB (brilliant green lactose bile) culture MPN (most probable number) method.

4) Discharge on the water quality observation date.

## 6. Socio-cultural Characteristics

The Ashio Copper Mine was discovered in 1610 (Edo era) by two farmers. In the early days, the mine was under the direct administration of the Tokugawa shogunate. In the 10<sup>th</sup> year of Meiji (1877), its administration was transferred to the management of Mr. Ichibei Furukawa. The mine was electrified and modernized, and bold innovations and improvements resulted in it becoming the nation's foremost copper mine nearly. Nearly 40 % of the yearly national production of copper was produced at this time, and the population of Ashio Town (38 400 persons in 1911) became the second largest in Tochigi Prefecture. On the other hand, polluted water from the mine caused fish kills several times in the downstream and deposited sediments causing problems to the farmers. The environmental pollution struggle between farmers and the company started in 1890. The leader of this struggle, Shozou Tanaka, who had been a member of the Diet, made a direct appeal to the Emperor in 1901 to request a stoppage of the mining. In this way, Watarase-gawa was the cradle of environmental pollution struggle in Japan. In the present time, the polluted area was treated and turned into a part of the Watarase Retarding Basin.

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