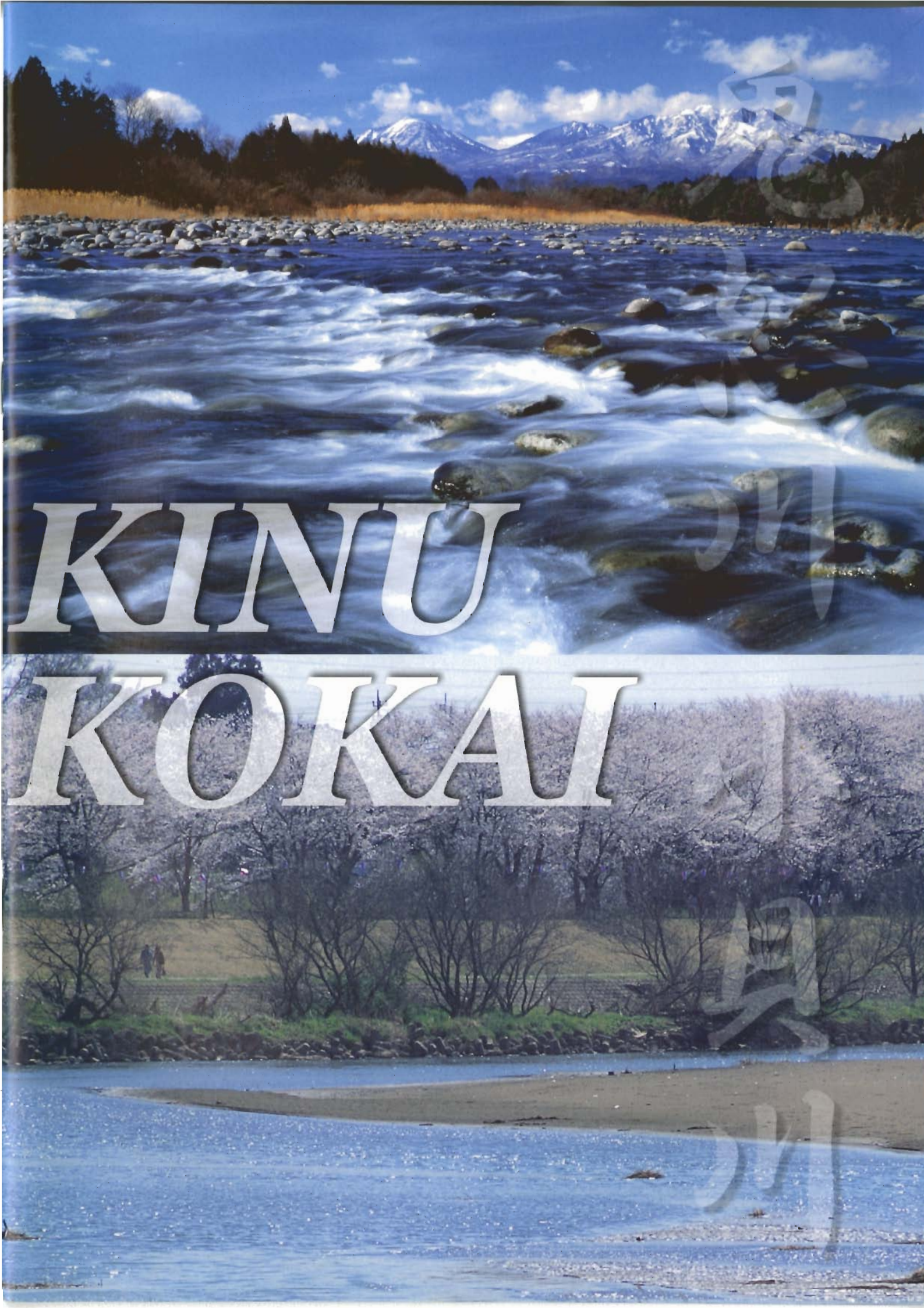
KINU
KOKAI

Published by

Foundation of River & Basin Integrated Communications, JAPAN

Nissei Hanzomon Bldg., 1-3, Kojimachi, Chiyoda-ku, Tokyo

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Cooperation

Ministry of Land, Infrastructure and Transport
Shimodate Work Office
Nikko Sabo Work Office
Kinugawa Dam Integrated Control Office
Yunishikawa Dam Work Office

Pictures: Cover Top/ Osamu Nobuhara
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The Kinu River originates at Lake Kinu near the border between Tochigi Prefecture and Gumma Prefecture, then at Moriya City in Ibaraki Prefecture, it flows into the Tone River that drains the largest river basin in Japan.

The Kokai River originates in a pond in Minaminasu Town in Tochigi Prefecture and flows into the Tone River in Tone Town in Ibaraki Prefecture.

Long ago, the Kinu River was an independent river that flowed into the Katoriumi that flowed on to the Kashima Sea. The Kokai River was one of its tributaries.

The eastward redirection of the Tone River, which was a huge river improvement project carried out by the Edo Regime, separated the Kinu River and the Kokai River to form the present river system.

At the same time as this river improvement project, many water supply and drainage facilities were constructed in the drainage basin, beginning with the three weirs on the Kokai River that were later known as the Three Great Water Supply Weirs of the Kanto. Many new paddy fields were developed on former marshland, creating a fertile grain growing region.

This booklet presents a wide range of information including the topography, climate, history, economy, and environment of the Kinu River Basin and the Kokai River Basin in a form that is easy for the members of the public to understand. We hope that this booklet will stimulate the interest of as many people as possible in the Kinu River and Kokai River.

Oka Weir (Kokai River)

Sanuki head works (Kinu River)

The Tone River and the Kinu and Kokai Rivers

The Kinu and Kokai Rivers are, respectively, the longest and second longest among all the tributaries of the Tone River. The combined basin area of the two rivers makes up a large proportion (17%) of the Tone River Basin.

●Profile of the Kinu River

Water source: Lake Kinu located on the border between Tochigi and Gunma Prefectures

Length of the main river channel	176.7 km
Total channel length	746.0 km
Total basin area	1,760.6 km^2
Arable land in the basin	30,000 ha
Population in the basin	550,000 persons
Population in the probable flood areas	480,000 persons

●Profile of the Kokai River

Water source: Lake Kokai located in Minainasu Town, Tochigi Prefecture

Length of the main river channel	111.8 km
Total channel length	474.5 km
Total basin area	1,043.1 km^2
Arable land in the basin	50,000 ha
Population in the basin	550,000 persons
Population in the probable flood areas	60,000 persons

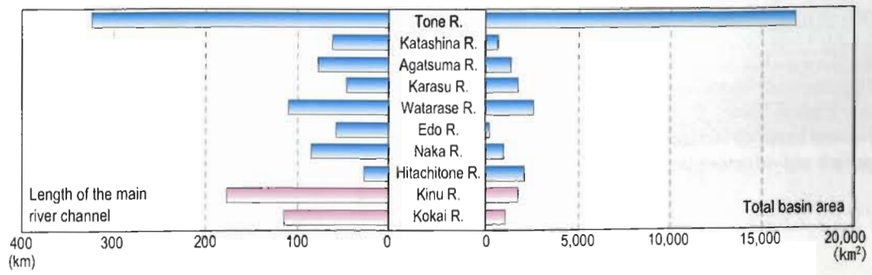
Main tributaries of the Tone River

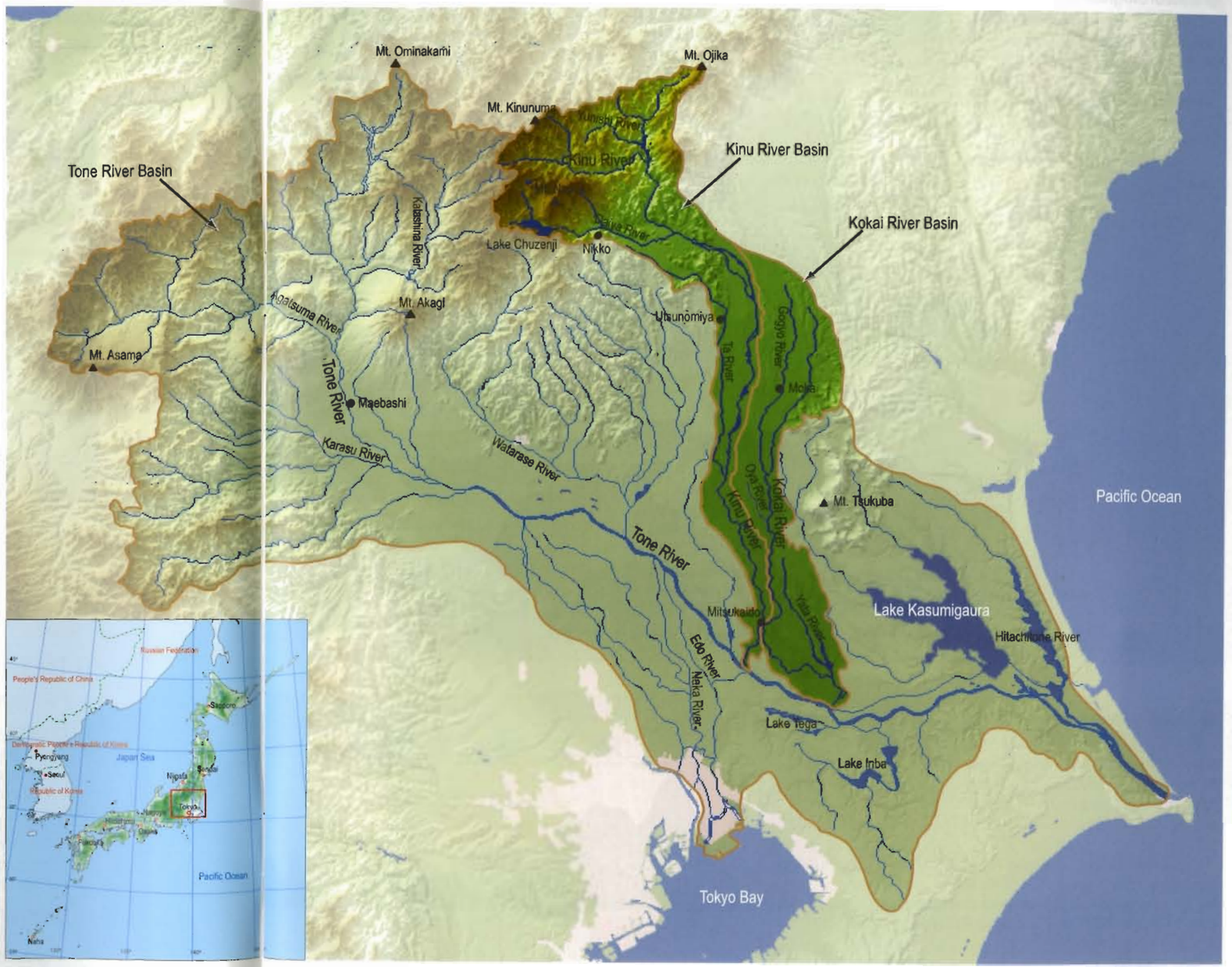
River name	Total basin area km^2	Length of the main river channel km
Tone R.	16, 840. 0	322. 0
Katashina R.	673. 1	60. 8
Agatsuma R.	1, 365. 9	76. 2
Karasu R.	1, 800. 7	45. 2
Watarase R.	2, 601. 9	107. 6
Edo R.	200. 3	54. 7
Naka R.	986. 7	82. 2
Hitachitone R.	2, 156. 7	27. 5
Kinu R.	1, 760. 6	176. 7
Kokai R.	1, 043. 1	111. 8

Main tributaries of the Kinu and Kokai Rivers

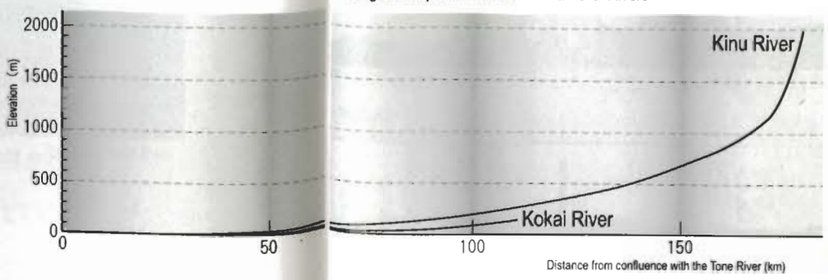
River name	Total basin area km^2	Length of the main river channel km
Kinu R.	1, 760. 6	176. 7
Ojika R.	240. 0	34. 6
Yunishi R.	102. 5	25. 8
Daiya R.	256. 1	29. 9
Ta R.	260. 0	78. 1
Kokai R.	1, 043. 1	111. 8
Gogyo R.	239. 4	52. 4
Oya R.	59. 0	19. 6
Yata R.	168. 6	42. 5

Comparison between main tributaries of the Tone River and the Kinu and Kokai Rivers





Longitudinal profile of the Kinu and Kokai Rivers



Water source of the Kinu River (Lake Kinu)

Water source of the Kokai River (Lake Kokai)

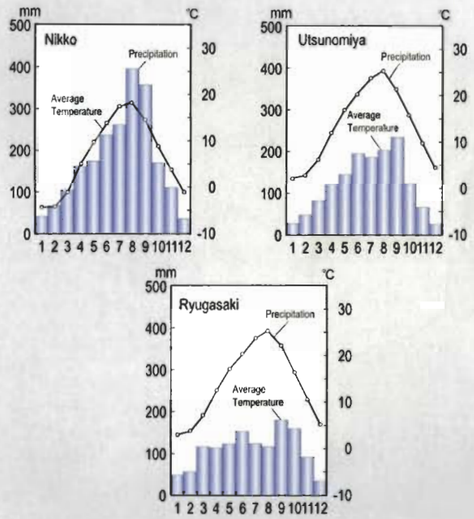
Nature and Communities in the Basin

●Meteorological characteristics

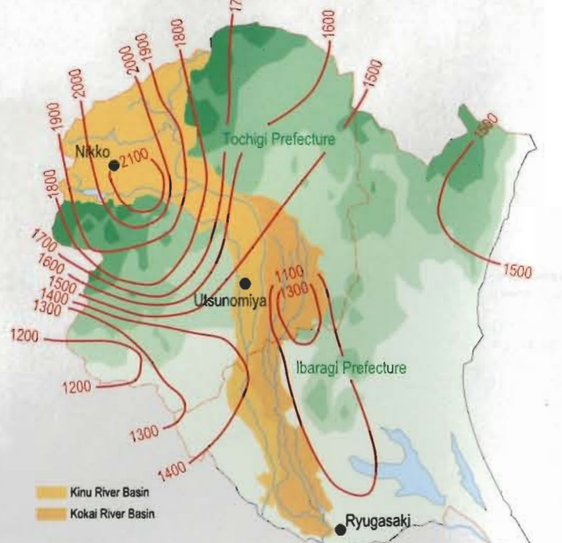
Whereas the average annual rainfall in Japan is about 1700 mm, that in the Tone River basin is 1300 mm. An analysis of the regional distribution of annual rainfall in the Kinu and Kokai Rivers Basins shows wide variations: 1600 mm to 2000 mm in the mountain areas and 1200 mm to 1400 mm in the plain areas.

Snow as well as rain is an important source of water for the Kinu River. The mountain areas receive snowfall as the northwestern seasonal winds and low-pressure centers pass along the southern coast of Honshu, and snow accumulation of 10 cm or more lasts for 30 to 50 days. The cumulative snowfall is about 210 cm in Nikko, which is relatively small compared to the 1,000 cm that falls in Oku Tone (the upper reaches of the Tone River).

There are wide fluctuations in temperature from one area to another due to large differences in altitude and complex topographic features, as well as the fact that the entire basin is located inland. The difference in temperature is 5°C or more between the mountain and plain areas.



Monthly average precipitation and temperature (1971-2000)



Annual Precipitation (mm) (1941-1970)

●Topographic features of the basin

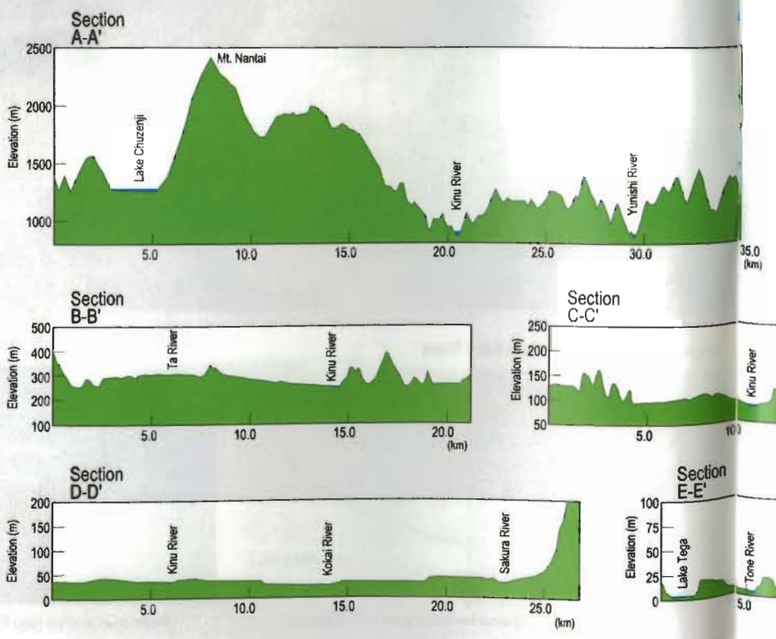
Upstream, the Kinu River runs through mountains 500 - 2,500 m high with deep valleys. After the river merges with the Daiya River, it runs across an alluvial fan to the south, creating river terraces in many places and eroding the high plains before joining the Tone River.

The water source for the Kokai River is at a low altitude: the river runs gently through flat land of 500 m or less in altitude. The alluvial low lands that stretch from the confluence of the Gogyo and Daiya Rivers are mostly used as paddy fields.

The Kinu and Kokai Rivers are characterized by large flat areas, 34% and 83% respectively, compared with the national average of 20%.

		Kinu River	Kokai River
Basin Area	km²	1760.6	1043.1
Mountainous Area	km²	1110.1	154.8
	%	61.8	15.0
Flat Area	km²	617.0	853.6
	%	34.3	82.5

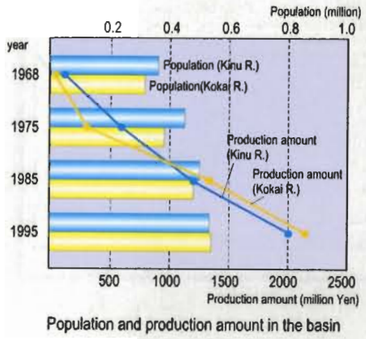
Proportion of Mountainous Area to Flat Area in the Kinu and Kokai River Basin



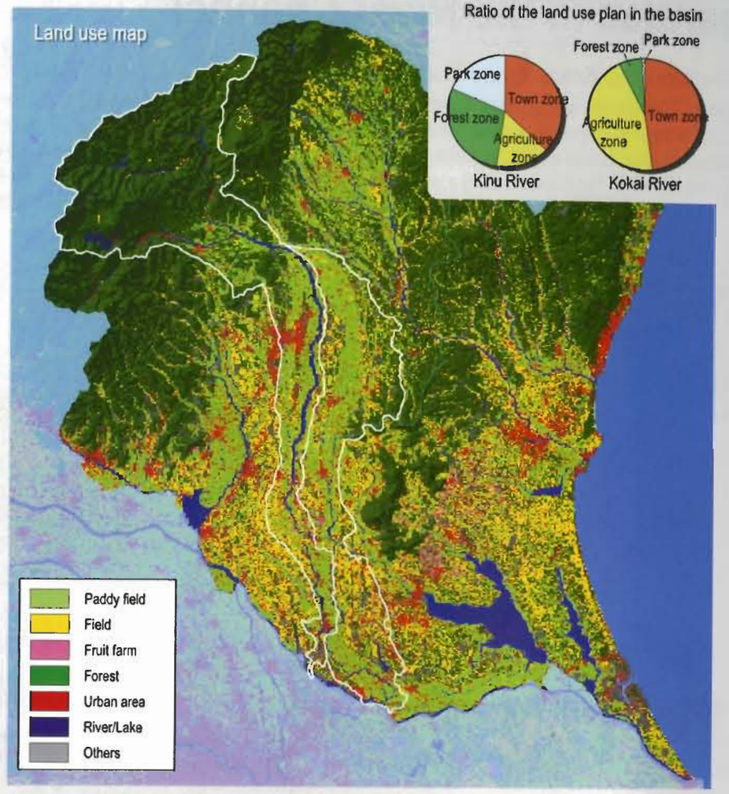
●Land use and population

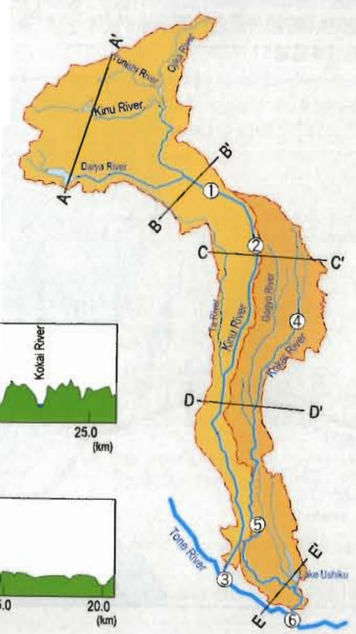
The plains in the basin have long been centers of sericulture and rice-growing, and constitute a major rice growing area that spreads across Tochigi and Ibaraki Prefectures. The Kinu and Kokai Rivers serve as major sources for the intake and discharge of water.

Along the rivers lie the cities of Imaichi, Utsunomiya, Moka, Oyama, Yuki, Shimodate, Shimotsuma and Mitsukaido, where industrial complexes are being developed. Tsukuba Science City also lies within the basin.



Population and production amount in the basin





Flow of the Kinu River

①Beginning of the formation of alluvial

②Braided flow and open levee

③To the Tone River

Flow of the Kokai River

④Flowing through flat lands

⑤Expansive paddy field

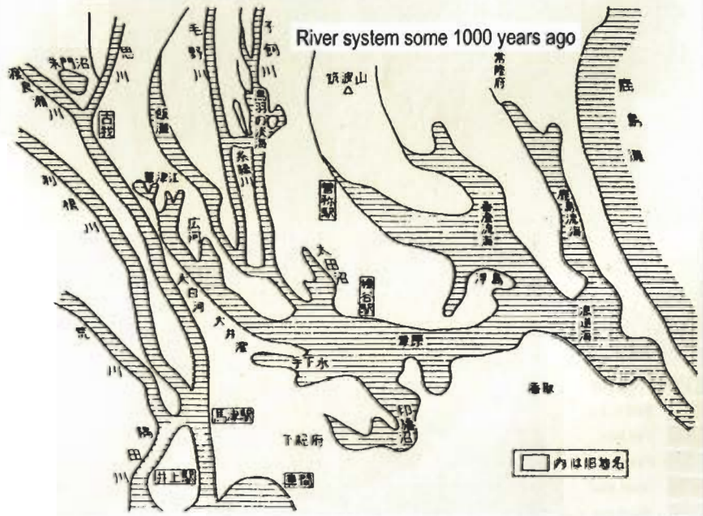
⑥To the Tone River

History of the Kinu and Kokai Rivers

Changes in the River Channel

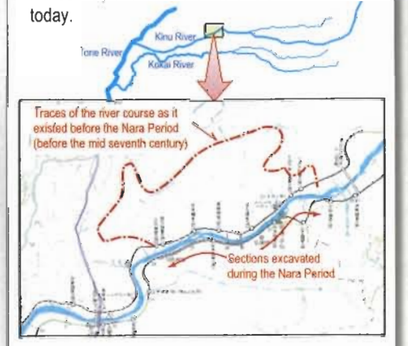
●The Kinu and Kokai Rivers in ancient times

Some 1000 years ago, the Kinu River, which starts high in the mountains of Nikko, split into two tributaries between Shimotsuma City and Yawara Village in Ibaraki Prefecture. One tributary, running eastward, passed through what is today called the Itokuri River, then Toba-no-umi and formed what is now called the Kokai River. The other tributary ran southward through what is now called the Kinu River channel, flowed into a swamp called Ashihara, creating a large inland sea called Katoriumi, then emptied into the Pacific Ocean near Choshi City.



Visible traces of past improvement work

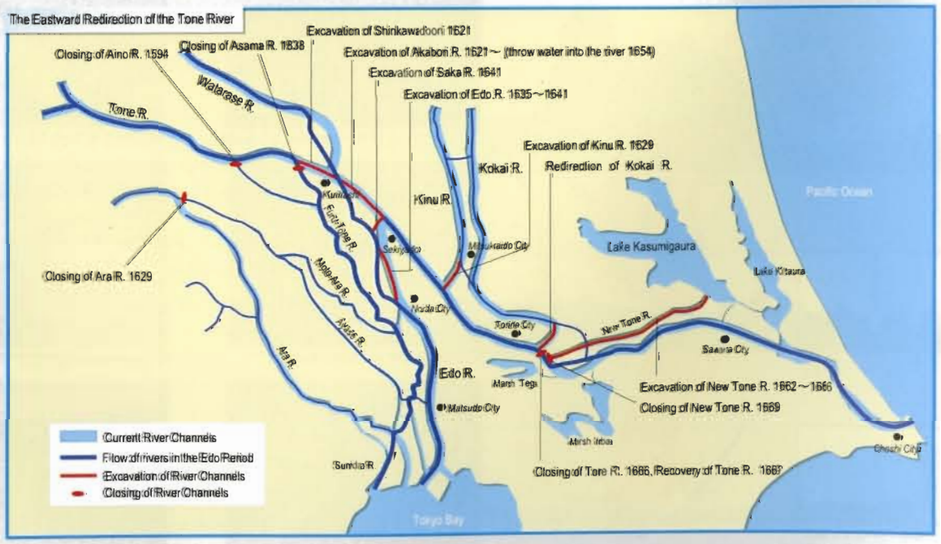
The Kinu River is a flood-prone river that has inundated its drainage basin since ancient times. The Zoku-Nihonki (Sequel to the History of Early Japan) reports large-scale river work carried out in 768 AD, and traces of its ancient flow remain today.



●Eastward redirection of the Tone River

It was Tokugawa Ieyasu who transformed the Tone River that flowed into Edo Bay, into the river as it is today.

After Ieyasu moved to Edo Castle in 1590, he laid the foundation of today's Tone River system that flows down to Choshi, by diverting the river that flowed into Edo Bay (present Tokyo Bay) to the Watarase and Hitachi Rivers. The river improvement work was carried out over a period of about 60 years and is called the eastward redirection of the Tone River. The work began with the closing of the Aino River in 1594 in the early Edo period and ended with the routing of water to the Akahori River in 1654.

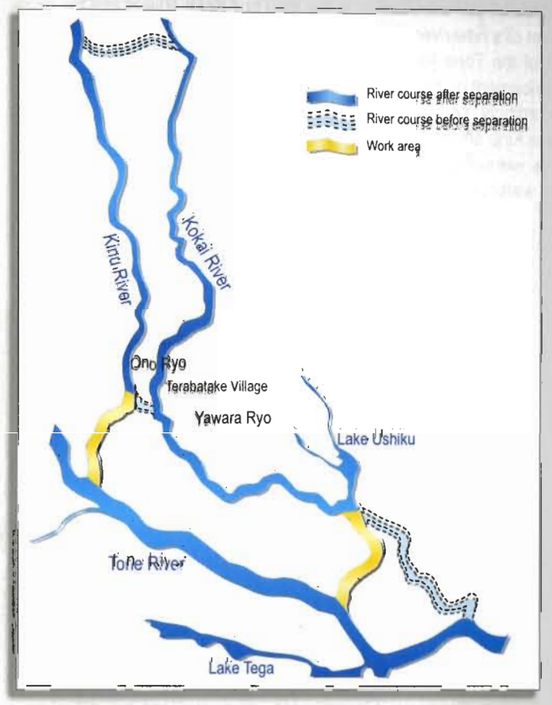


●Separation of the Kinu and Kokai Rivers

The separation of the Kinu and Kokai Rivers carried out as part of the eastward redirection of the Tone River began in 1608 and was completed between 1615 and 1624. The objectives of the project were as follows.

The first was to protect the large swampy areas of Yawara Ryo (Yawara area) and Ono Ryo (Ono area) from flooding by separating the Kinu and Kokai Rivers and to develop new paddy fields. Another objective was to use the two rivers for water transportation of passengers and freight.

A picture depicting the difficult work of separating the Kinu and Kokai Rivers carried out in the former Terabatake Village.

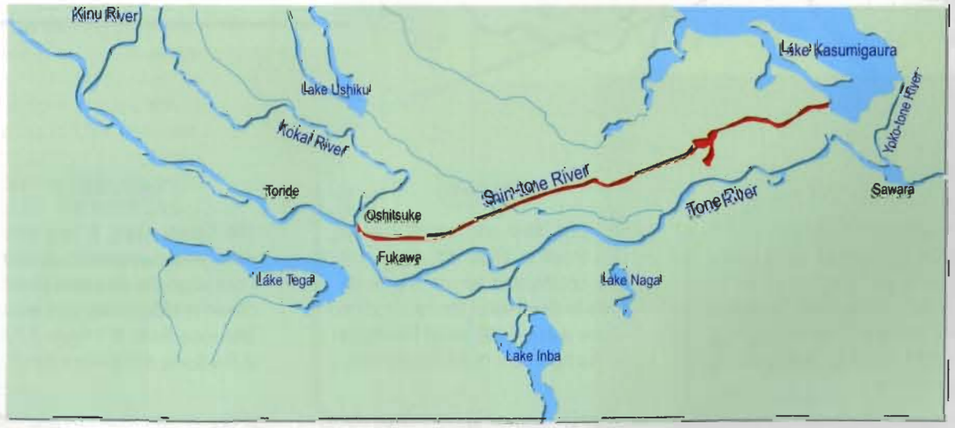


●Excavation of the Shin-tone River channel and closing of the Tone River

After completion of the eastward redirection of the Tone River, the Tokugawa Shogunate next set about reclaiming Lakes Tega and Inba. To redirect the flow of the Tone River farther eastward, the river was closed in 1666 at Oshitsuke Village located at the confluence of the Kokai River and Tone River, and a Shin-tone River channel, 32 km long in total, was excavated parallel to the original Tone River channel toward Lake Kasumigaura, under the direct rule of the Tokugawa Shogunate.

However, the Shin-tone River channel suffered from insufficient water that hampered water transportation, and overflowed onto arable land along the river during flooding, causing suffering to peasants.

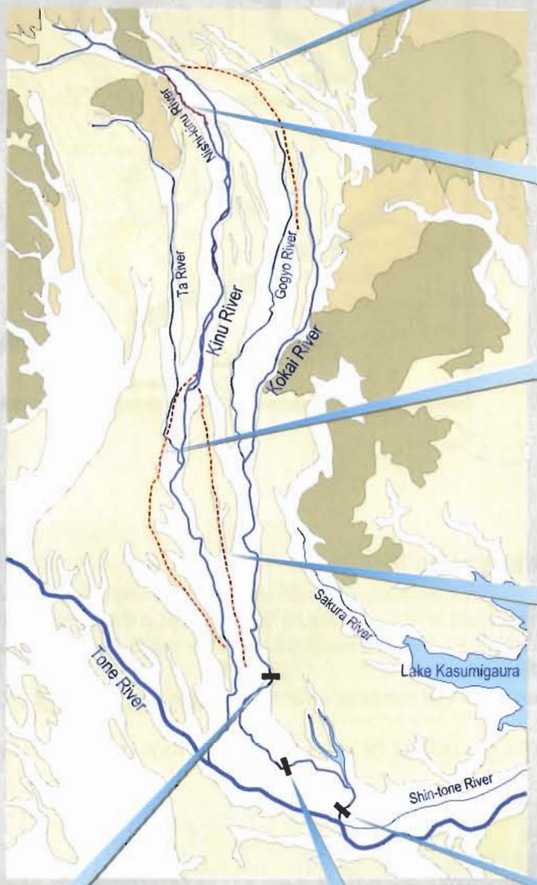
For this reason, in 1669, only three years after the opening of the new channel, the intake at Oshitsuke Village was closed and the Tone River channel was restored to its former location.



New Paddy Field Development

●Construction of drainage channels in the Edo Period

The complete separation of the Kinu and Kokai Rivers and the excavation of a new river channel carried out as part of the eastward redirection of the Tone River by the Tokugawa Shogunate enabled full-scale development of the entire flood plains of both the Kinu and Kokai River. Accordingly, new paddy fields were developed at an accelerating pace in the Kinu and Kokai Rivers basins, and many new villages and arable lands were created. It was essential, therefore, to ensure the availability of water sources and construct drainage channels.



Ichinobori Irrigation Canal

The Ichinobori Irrigation Canal, completed in 1656, was later expanded in scale to supply water to 13 villages and 2,300 ha of land.

Sakaki Irrigation Canal

With the foundation of the union of 47 villages in 1754, the Nishi Kinu River, a distributary of the Kinu River, which had been used as a main irrigation canal, came to be known as the Sakaki Irrigation Canal. The total area served by water from the irrigation canal was 1,720 ha in 1909.

Yoshida Irrigation Canal

After it was completed in 1725 as a channel to supply water to the Iinuma paddy fields that Isawa Tamenaga began developing in 1723, it supplied valuable water to 88 villages.

Ezure Irrigation Canal

The Ezure Irrigation Canal was first excavated in 1726 as an alternative to three reclaimed ponds of Taihonuma, Enuma and Isanuma. However, the canal could not function properly and fell into disuse about 60 years later due to a decrease in water level in the Kinu River and the eruption of Mt. Asama.

Fukuoka Weir

The Fukuoka Weir was first known as the Tsukidome Weir when it was constructed in Yamadanuma in 1625 to adjust the water flow and was later used to develop 3,000 ha of land that came to be known as the Yawara Ryo.

Oka Weir

The Oka Weir was constructed at Oka Point in 1630. An earth weir was constructed across the Kokai River to divert water for the irrigation of the entire 1,900 ha of Kita-soma on the right bank of the Kokai River.

Toyota Weir

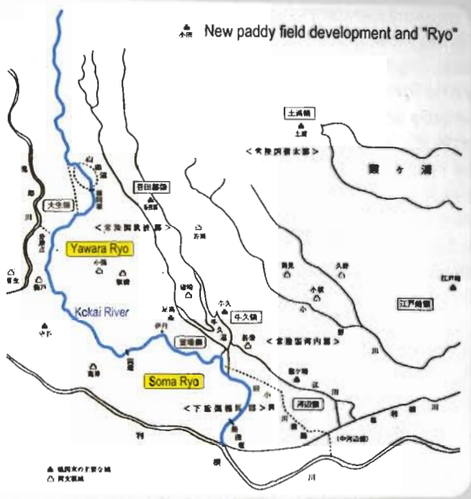
The Toyota Weir, a river crossing weir, was constructed at Haneno Point when the Shin-tone River was closed in 1632. Water was led to the Shin-tone River to irrigate 1,700 ha in the Soma and Yawara Ryo.

●Three major water supply weirs in Kanto

The Fukuoka, Oka and Toyota Weirs were constructed in the Kokai River by the Ina Clan following the start of full-scale development of the entire flood plains of the Kokai River. This led to the creation of new paddy fields, which later came to be known as the Yawara Ryo yielding 30,000 koku of rice and the Soma Ryo yielding 20,000 koku of rice. These three were among the largest weirs in Kanto using the pond method, which was the most often used method during this period.

Wooden frame of the Fukuoka Overflow Weir (Constructed in 1896, it was used until 1923)

Entire view of the Oka Weir after 1899 sketched by artist Akamatsu Shijiro



Map of the Toyota Weir during the Ansei Period (1854 - 1860) (Drawings of Fukawa Village, by Akamatsu Sotan, retouched)

Restoration of three ponds and Ezure Irrigation Canal

Villages suffered from water shortages due to increasing difficulty in taking water from the Ezure Irrigation Canal as a result of the lowering of the riverbed level in the Kinu River during the 1764 - 1780 period, the ash fall from the eruption of Mt. Asama in 1783, and a series of floods that damaged water intake facilities and irrigation canals. This led to a long-term struggle in the middle reaches of the Kinu River to restore three ponds including Isanuma and the Ezure Irrigation Canal.

A view of rice planting in the Edo period

Connecting Edo and Oshu - Water Transportation along the Kinu River -

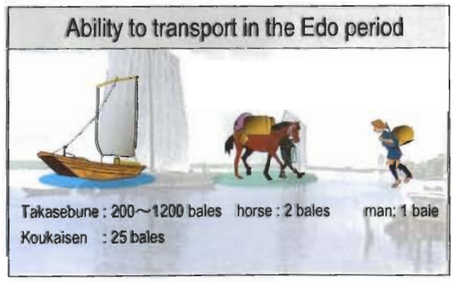
●Water transportation along the Kinu River

The eastward transfer of the Tone River system helped to create a major waterway network in the Kanto region, which served as arteries for the distribution of goods for the Tokugawa Shogunate.

The Kinu River, which was a part of the network, played an increasingly important role as the waterway connecting feudal domains in Tohoku and Edo for transportation along the Tone River system, since its separation from the Kokai River enabled large boats to travel upstream. The Kinu River was used to transport products from feudal domains in Tohoku as well as Oshu rice that reportedly accounted for two thirds of all rice consumed in Edo. It was also reported that the Aizu Wakamatsu Clan, which most often used water transportation along the Kinu River, carried between 120,000 and 130,000 horse loads of goods into Edo each year. The boatloads of goods brought to the banks of the Kinu River were diverse including rice destined for Edo, lacquerware and wax from Aizu, tobacco and unrefined hemp from Fukushima and safflower from Yamagata. Salt was the most important product shipped from Edo to the Oshu region.

Outward journey (to Edo)	Rice, soybeans, adzuki-beans, wheat, tobacco, wax, saffron, ramie, perilla sesame, paper, silk floss, cotton seed, lacquer ware, rice wine, soy sauce, charcoal, firewood, rope, straw mats, etc.
Return journey	Salt, tea, small wares, milled grains, fertilizer (dried sardines, oil cake), etc.

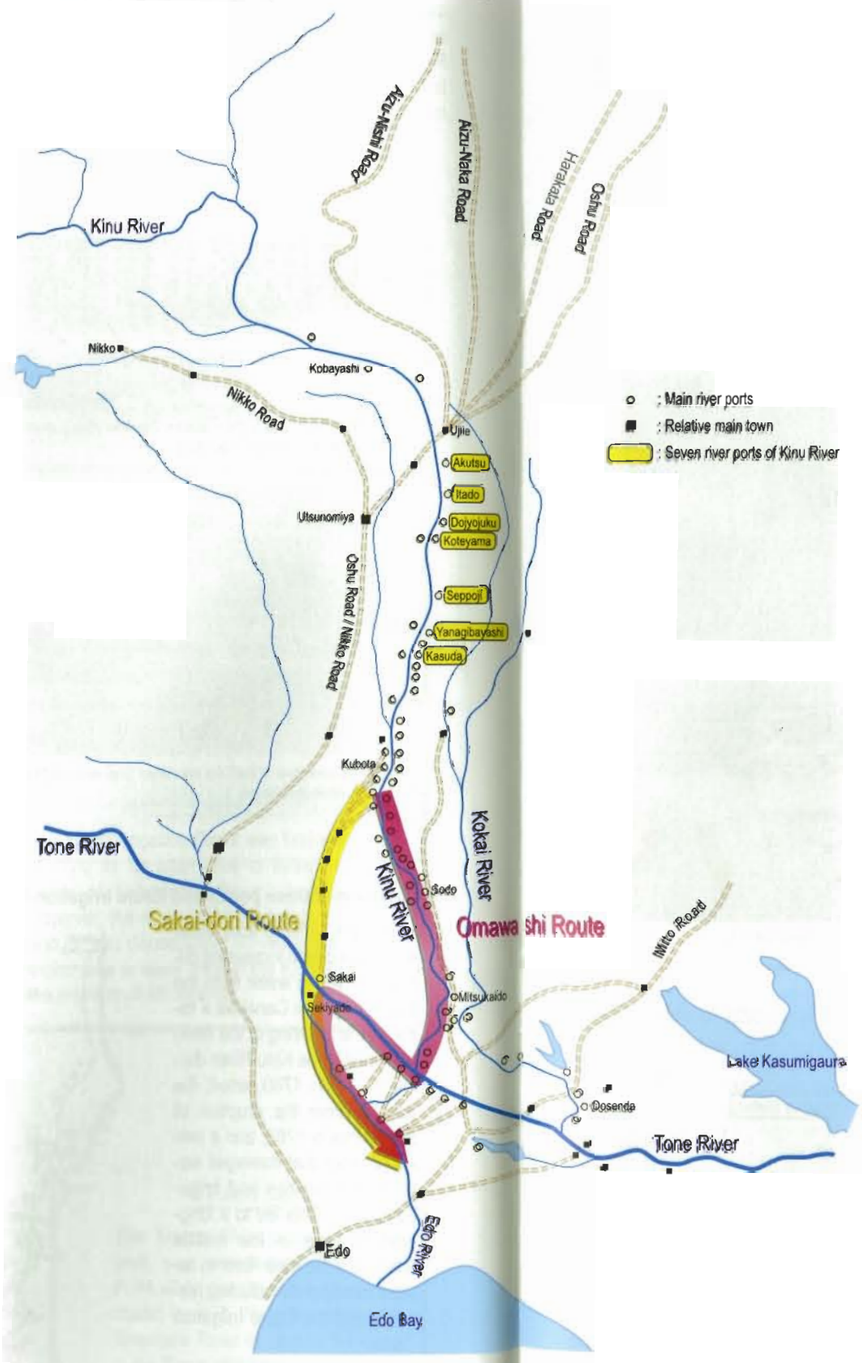
Ability to transport in the Edo period



●Water transportation route along the Kinu River

Originally, cargoes were transported from the upstream riverbanks to Edo by two routes. One was the Through Sakai Route (Sakai-dori). Cargoes transported on this route were unloaded at Kubota and other locations in the middle reaches of the river, then carried by land (Tsukekoshi) to Sakai Landing at the convergence of the main course of the Tone River and the Edo River. The other route was the Long Route (Omawashi). In this case, cargoes were transported all the way to the Tone River, then back upstream to the Sakai Landing and on to the Edo River. These routes were both protected by the Edo Regime (Bakufu), but a succession of new routes were sought and developed to carry cargoes faster and more cheaply.

Map of water transportation along the Kinu and Kokai Rivers



: Main river ports
: Relative main town
: Seven river ports of Kinu River

●Development of river ports

Areas along the river where main roads crossed flourished. Upstream river ports of the Kinu River, and seven left ports in particular located immediately downstream from the point where the Oshu Road crossed the Kinu River, developed as a gateway for receiving products from the Tohoku region.

In the middle reaches of the Kinu River, the Kubota river port and other river ports flourished as sites for reloading cargo carried from upstream by small wooden flat-bottomed boats onto large flat boats or as the sites for reloading cargo for land transportation to the Sakai river port.


Largest river port in the upper Kinu River 「Akutsu river port」


Largest river port in the middle Kinu River 「Kubota river port」

Seven River Ports System

Seven river ports, Akutsu, Itado, Dojyojuku, Koteyama, Seppoji, Yanagibayashi, and Kasuda located in the upper reaches of the Kinu River, all on the left side, were used for the transportation of various products mainly from Oshu and Shimotsuke. To ensure smooth interactions and protect the common interest of these ports, the Funawari system was introduced to promote equity in workload (in terms of the frequency of use of river boats to carry cargo), by equally allocating shipments. This system is called the Seven River Ports System.

●Koukaisen

Small, lightweight wooden flat-bottomed boats(Koukaisen) with a shallow draft played a leading role in water transportation along the Kinu River since they could easily be used in upstream shallows and rapid streams and could be towed. The carrying capacity was up to 25 bales of rice.


Koukaisen going to the Kinu River

●Rafting

The Kobayashi river port, the most upstream right bank of the Kinu River, located upstream of the Akutsu river port, was used specifically for rafting. Logs cut from the mountains of Imaichi, Nikko and Fujihara were collected and made into rafts here, for floating down the Kinu River. The rafts were sometimes as long as 40 m.


Figure of rafting

Protecting the Basin

Flood Problems in the Past

●Records of flooding

Levees along the Kokai River have broken at the rate of once every six to seven years during the last 300 years. To solve this problem, civil engineering and flood control works have repeatedly been carried out. However, flooding has been occurring continuously.

Floods in the Kinu River

The Kinu River is characterized by a vulnerability to the rain that falls on a range of steep mountains located in the upper reaches of the river.

Upstream dams that have been completed in recent years can regulate the flood waters sharply reducing floods.

Floods in 1938

Major floods occurred twice in June and September in 1938.

In June, a flood hit the downstream plains of the Kokai and Kinu River as a result of extremely heavy rainfall.

In September, a typhoon that swept through the western part of the Kanto region caused a major flood in the Kinu and Kokai Rivers, breaking levees and causing overflows in many places.

Mitsukaido City

Area in front of Shimodate Station in Shimodate City

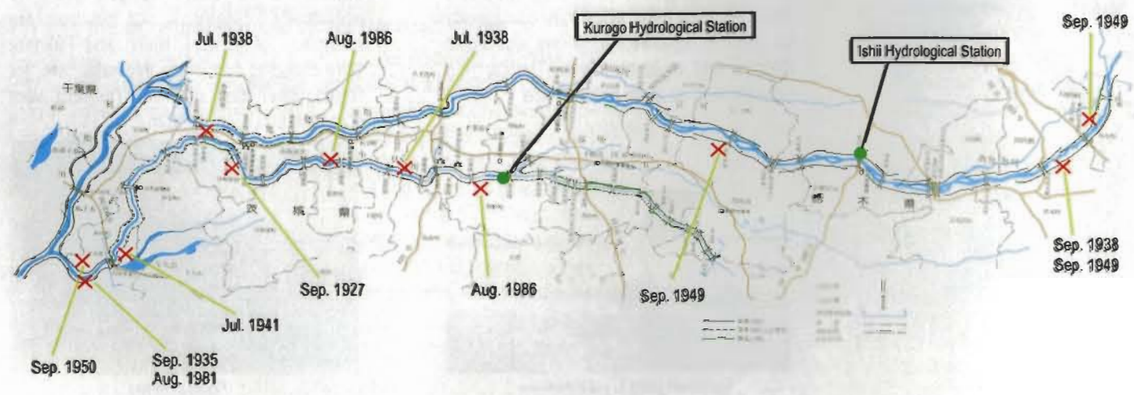
Flood in 1981

Typhoon No. 15 in 1981 caused the water level to exceed the warning water level in 16 rivers constituting seven river systems in Kanto alone. As a result of the major flood in the Tone River, the backflow of the Tone River broke levees in Takasu in Ryugasaki City, on the downstream left bank of the Kokai River, and caused tremendous damage; 3,396 ha and 5,847 houses were flooded.

The examples of floods that caused downstream damage due to the backflow of the main Tone River even though floods in the Kokai River alone was small are those that occurred in September 1935, September 1948 and August 1950.

Takasu, Ryugasaki City

●Breach point



Floods in the Kinu River

The Kokai River is characterized by the long time of flood duration because of a large plain area that creates a gentle river gradient. This also prolongs the time for the retreat of flood waters and makes the river susceptible to the backflow of the Tone River.

Flood in 1986

The rainfall brought by Typhoon No. 10 in August 1986 was so heavy that the average rainfall in the Kokai River Basin exceeded 300 mm during the period of almost 24 hours.

The overflow first occurred in upstream areas with no levees, flooding about a quarter of Shimodate City, and then broke levees in Akahama, Akeno Town and Toyota, Ishige Town, flooding 4,300 ha and 4,500 houses.

Shimodate City

Toyota drainage channel, Ishige Town

Hakojima district

Flood in 1999

Heavy rain was produced by a tropical cyclone and seasonal rain front in the Kokai River Basin between July 13 and 15, 1999.

In Ichikai Town and Mashiko Town, 11 houses were flooded below floor level and 171.4 ha of cultivated fields were flooded.

Area around Kokai Bridge

●Records of floods in the Kinu and Kokai Rivers

River	Kinu River (Ishii point)					Kokai River (Kurogo pint)						
Date of flood / Item	1935 Sep.	1938 Sep.	1947 Sep.	1949 Aug.	1982 Sep.	1935 Sep.	1938 Jun.	1941 Jul.	1950 Aug.	1966 Jun.	1981 Aug.	1986 Aug.
Average 3-day rainfall in the basin	—	294	300	286	297		297	228	—	183	207	318
Water level Y.P+m	—	4.08	3.80	4.25	1.78	—	5.10	5.05	—	5.10	—	6.86
Peak discharge (m^3/s)	2,200	5,401	4,024	5,700	2,240	—	—	—	—	300	—	1,320
Cause	Torrential rain caused by a warm front generated by a typhoon	Torrential rain caused by a typhoon	Torrential rain caused by a typhoon (Typhoon Kathleen)	Torrential rain caused by a typhoon (typhoon Kitty)	Torrential rain caused by an autumnal front generated by a typhoon	Damage to the downstream Kokai River basin due to the backflow of the main Tone River	Torrential rain caused by a typhoon	Torrential rain caused by a seasonal rain front and typhoon	Damage to the downstream Kokai River basin due to the backflow of the main Tone River	Torrential rain caused by a typhoon	Damage to the downstream Kokai River basin due to the backflow of the main Tone River	Torrential rain caused by a typhoon

Ishii point : Warning water level:Y.P+2.000m, Design high water level:Y.P+3.934m
Kurogo point : Warning water level:Y.P+3.800m, Design high water level:Y.P+6.033m
Y.P : Yedokawa Peil (=Mean Sea Level of Tokyo Bay -0.840m)

Improvement of the Kinu and Kokai Rivers

●Kinu River improvement plan

Full-scale improvement of the Kinu River began in 1926. The improvement plan included the regulation of flood flows by yet-to-be-constructed upstream dams and the water retarding effect of the wide river channel of the Kinu River, to ensure that the water flow of the main Tone River would not exceed its design flood discharge, in addition to the regulation of surplus water using the Tanaka, Sugou and Inadoi retention ponds, all scheduled to be constructed along the main Tone River.

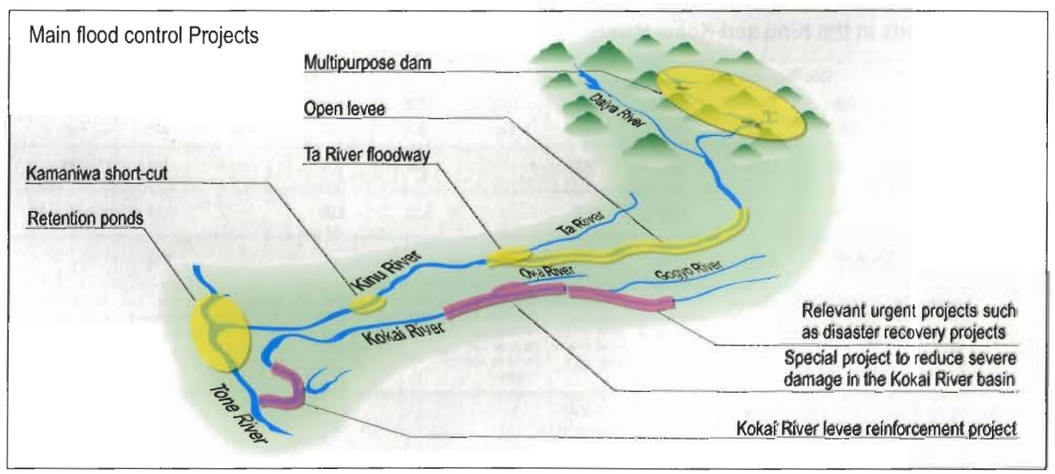
Formulated year of improvement plan	Design flood discharge (m^3/s) Ishii point	Mitsukaido point	Discharge flows into the Tone River (m^3/s)	Improvement area
1926	3,600	2,600	890	110 km from Tone River junction
1932	3,790	2,680	960	110 km from Tone River junction
1939	4,000	2,300	900	110 km from Tone River junction
1949	4,000	3,300	0	101.5 km from Tone River junction
1973	6,200	5,000	0	101.5 km from Tone River junction
1981	6,200	5,000	0	3.0 km - 98.5 km from Tone River junction

●Kokai River improvement plan

Full-scale improvement of the Kokai River began from the downstream area in 1933 to rationalize the use of water by constructing embankments using former facilities and renovating the Oka Weir and other weirs. The current improvement plan aims to achieve the design flood discharge of 1300 m^3/s by constructing embankments and excavating the river channel along the 78 km section starting from the point 7 km upstream from the junction with the Tone River.

Formulated year of improvement plan	Design flood discharge (m^3/s) Upstream	Downstream	Discharge flows into the Tone River (m^3/s)	Improvement area
1933	300	450	—	8 km from Joban line railroad bridge
1938	—	750	—	42 km from Joban line railroad bridge
1942	600	850	0	42 km from Joban line railroad bridge
1946	600	850	0	83 km from Joban line railroad bridge
1981	650	1,300	500	78 km from Joban line railroad bridge
1986	850	1,300	—	9.6 km from Kokai bridge

Main flood control Projects



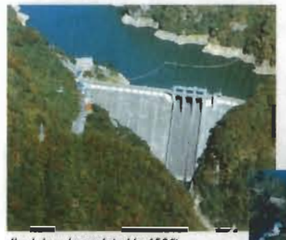
●Flood control of the Kinu River

Multipurpose dam

A multipurpose dam is designed for power generation, agricultural, municipal and industrial water supply and flood control. Well-known dams include the Kawamata, Ikari and Kawaji dams in the upper reaches of the Kinu River.

Specifications of the upstream dams

Dam name	Ikari dam	Kawamata dam	Kawaji dam
Type of dam	Overflow type concrete linear gravity dam	Dome type concrete arch dam	Concrete arch dam
Purposes	Flood regulation Irrigation Electric power generation	Flood regulation Irrigation Electric power generation	Flood regulation Irrigation Urban water supply
Effective storage volume	46 million m^3	73.1 million m^3	76 million m^3
Catchment area	271.2km^2	179.4km^2	144.2km^2
Annual in flow	330 million m^3	240 million m^3	120 million m^3
Irrigation area	8,941ha	8,941ha	7,149ha


Ikari dam (completed in 1956)


Kawamata dam (completed in 1966)


Kawaji dam (completed in 1983)

Textbook case of dam construction - Ikari Dam

The plan to construct the Ikari Dam in the Ojika River, a tributary on the left side of the Kinu River, was first prepared before the World War Ⅱ, as part of improvement of the Kinu River. However, the plan was abandoned because construction of the dam was technically impossible due to poor geological conditions. However, the plan was brought out again after the flooding in September 1938.

Although suspended during the war, full-scale construction of the dam was restarted in 1950 as part of the comprehensive Kinu River development project, the first comprehensive development project in Japan, and was completed in 1956.

The Ikari Dam, the first Japanese dam exceeding 100 m in height, is a concrete gravity dam constructed as a trial by Japanese engineers while learning the latest U.S. technologies. This dam became the model for dam construction in Japan and is regarded as a textbook case of dam construction.

Open levees (discontinuous levees) in the Kinu River

There are open levees in 22 locations along a 44-km section, starting from the 50.5 km point of the main Kinu River in Tochigi Prefecture. The present open levees were constructed between 1931 and 1966 along the section where the riverbed gradient is between 1/200 and 1/500, and are regarded as representative examples constructed along rapid streams.


Area around Kiraku bridge

Mechanism of the open levee

The open levee is designed to reduce the force of flooding by partially passing water through between levees. They are constructed on fast flowing rivers on steep land.

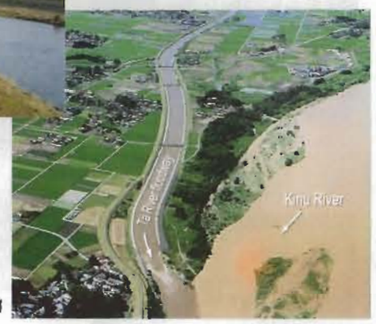
Kamaniwa short-cut

The excavation work to open the Kamaniwa short-cut to straighten the river channel was started in 1928 and completed in 1936. The curve in front of Kamaniwa (Chiyokawa Village) was so sharp that it not only retarded water flow during flooding but also made it difficult to protect river banks. A new 2,050-m long river channel was therefore excavated from the right bank in front of Kamaniwa toward the downstream direction to shorten the river channel by 2,350 m.

Ta River floodway

The highly meandering Ta River had repeatedly caused flood damage and threatened the lives of residents because there were some areas with no levees and other areas with low levees. However, the Ta River floodway, which was completed in 1972, helped to reduce downstream flood damage since it enables flood water to be discharged directly to the Kinu River.

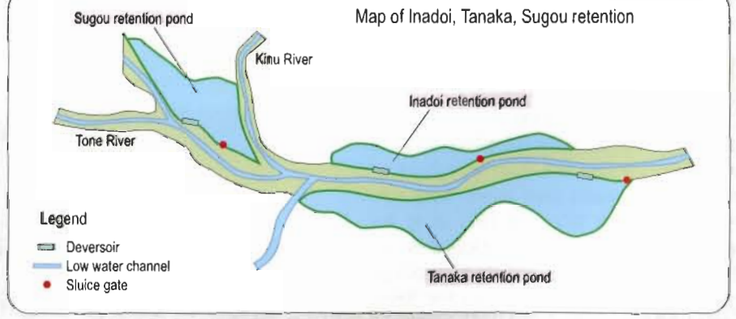

Ta River floodway at normal flow



Ta river floodway at time of flood

Inadoi, Tanaka and Sugou retention ponds

A plan was formulated to construct three retention ponds, the Tanaka, Sugou, and Inadoi Retention Ponds, near the convergence with the Tone River so that the total flow rate of the Kinu River will not affect the design flood discharge of the Tone River. The Tanaka and Sugou Retention Ponds have been completed and work to construct the Inadoi Retention Pond is now in progress.




Retention ponds at normal flow
(used as agricultural land)


Retention ponds at time of flood

Specifications of ponds

	Area (km^2)	Gross storage volume (million m^3)
Tanaka retention pond	11.75	95.53
Inadoi retention pond	4.48	30.80
Sugou retention pond	5.92	28.50

Flood control of the Kokai River

Special project to reduce severe damage in the Kokai River basin

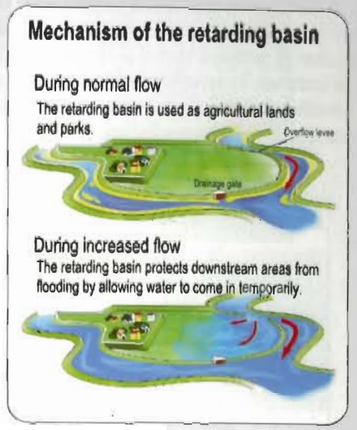
The flood caused by Typhoon No. 10 in August 1986 transformed the entire Hakojima district into a sea of mud, inflicting particularly severe damage to five distributed communities that suffered from flooding above floor level.

Restoration from the disaster was carried out over a five-year period under an urgent special project to reduce severe damage in the Kokai River Basin. The project focused on the relocation of the five communities and the formation of a retarding basin.

This project has set an unprecedented example of new town development in a retarding basin in Japan.

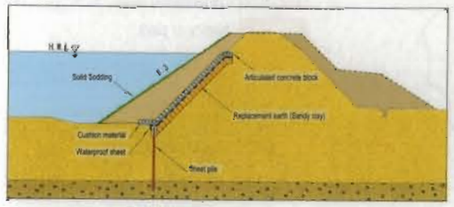

Flood in 1986


Completed Hakojima retarding basin



Kokai River levee reinforcement project

Since the Kokai River downstream from the Oka Weir is influenced by the main Tone River, the levee reinforcement project must take into consideration the cross section of the levee along the main Tone River. The project includes expansion of the levee width by about 10 m to prevent flooding of the Kokai River, reduction of the influence of the main Tone River, and prevention of water leakage.

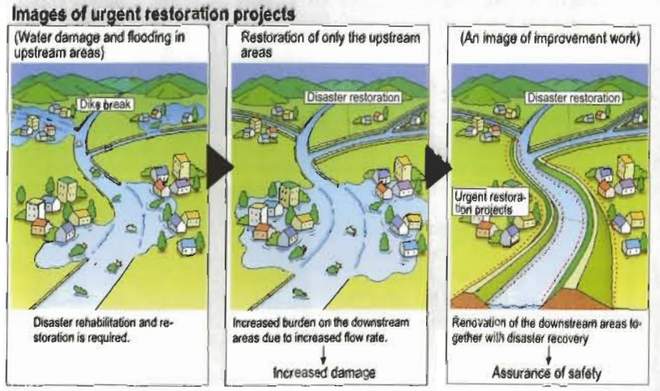



Area around Yawara Village

Relevant urgent projects such as disaster restoration projects

Until recently, construction work has focused on troubleshooting; for example, levees were constructed only along disaster-stricken locations. However, upstream construction work, for example, may cause downstream damage since what used to be upstream overflows now flow down the river. Therefore, urgent projects include intensive improvement of downstream locations vulnerable to overflows. In the upstream Kokai River, renovation work is underway involving the construction of levees and drainage systems after the flooding in 1999.

Images of urgent restoration projects




Area around Shimodate City

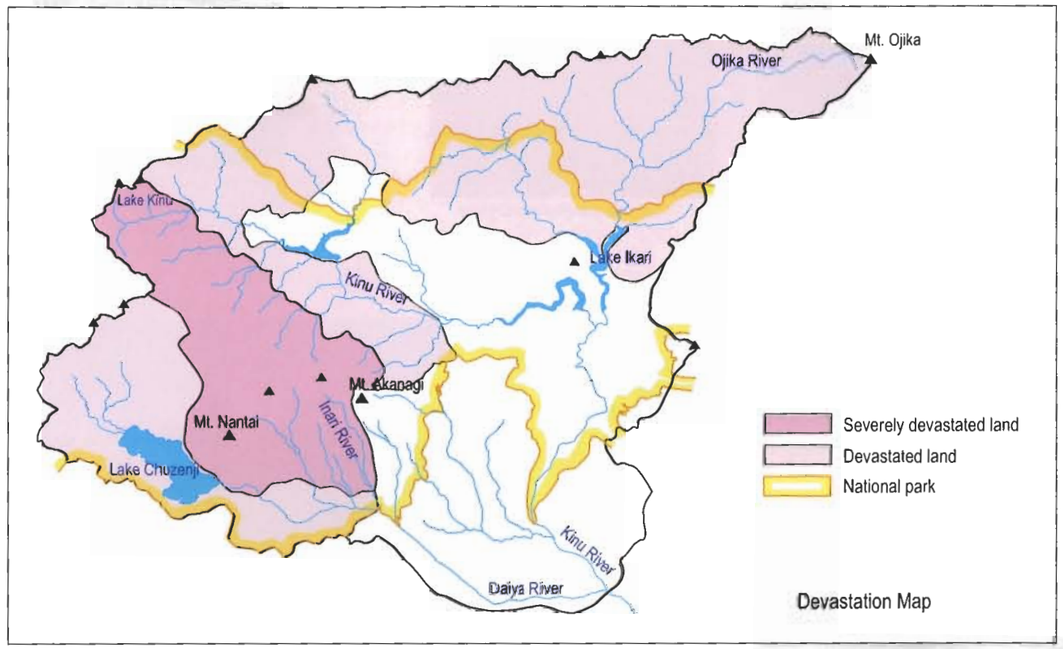
Protecting Water Resources - Sabo Works -

●Sabo (erosion and sediment control) project in Nikko

The upper reaches of the Kinu River, particularly the Nikko region in the Daiya River basin, are home to many world cultural heritage sites, yet the areas have repeatedly suffered severe damage due to a number of debris flows.

In 1918, a sediment control project began under the direct management of the national government in the Daiya River Basin focusing on the Inari River. Sediment control facilities that have been constructed include hillside works, sediment control dams and groundsill works. The construction of sediment control works has continued up to today. At the same time, with the collaboration of the Nikko Municipality, projects are now underway to establish a system to monitor debris flows triggered by rainfall and to issue alerts and evacuation information.

Another focus of the sediment control projects, apart from the prevention of disasters, is to protect the rich environment of local villages while ensuring harmony with nature. The projects are therefore promoted in consideration of the regional nature.



Devastation Map

●Major sediment disasters

Inari River flooding (1662)

The debris flows triggered by the large collapse of Mt. Akanagi upstream of the Inari River destroyed 300 private houses along the river and caused 140 deaths due to flooding.

Great Nikko earthquake (1682)

The debris flows triggered by the great earthquake dammed up the Ojika River, creating Lake Ikari. This caused the submergence of Ikari and Nishikawa Village and cut Aizu Nishi Road.

Major flooding of Lake Ikari (1723)

Continuous heavy rainfalls broke Lake Ikari created by the great Nikko earthquake, and the resulting debris flows containing large boulders reached as far as Utsunomiya and Moka, causing as many as 1,200 deaths.

Ashio typhoon (1902)

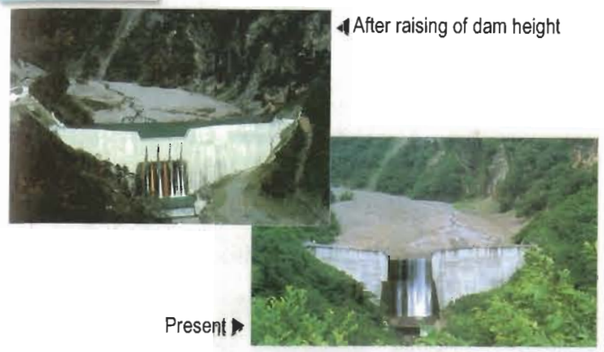
Large-scale debris flows at Mt. Nantai triggered by torrential typhoon rains poured into Lake Chuzenji and created tidal waves and consequently flooding in the Daiya River. The disaster caused more than 100 deaths, and 100 houses and Shin Bridge were washed away.

Typhoon No. 26 (1966)

Torrential rains similar to those in 1902 caused debris flows in the Inari River and other rivers. However, the damage was limited in the Daiya River Basin thanks to the sediment control facilities.

●Major Sabo Facilities

Hinata Sabo Dam

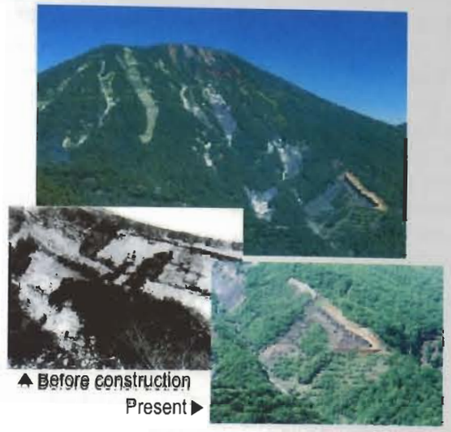


◀After raising of dam height

Present ▶

The Hinata sabo dam, located 5.2 km from the confluence between the Daiya and Inari Rivers, was completed in August 1928. Originally, the dam was 13.6 m high. Later on, between 1952 and 1953, the dam was raised by 6 m to 19.6 m high. The second raising of dam height was carried out on a large scale following Typhoon No. 26 in September 1966 and the work was completed in 1982. The Hinata sabo dam, 46 m in height, is one of the largest sediment control dams operated on a stand-alone basis in Japan.

Onagi hillside works

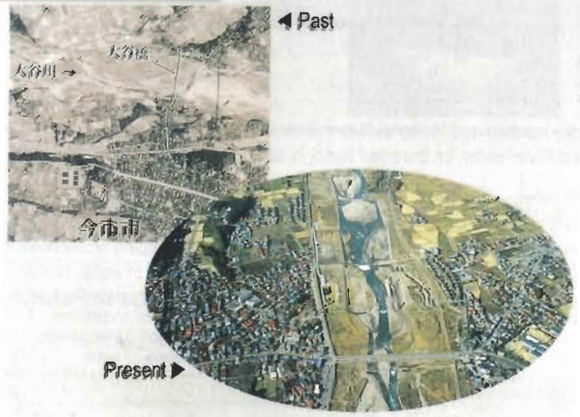


▲Before construction

Present ▶

Onagi is the site of a large-scale collapse triggered by a large earthquake and heavy rains in 1683, about 300 years ago. The collapse is still progressing today. The Onagi hillside works are designed to prevent debris flows from the failed site from causing major damage to downtown Nikko and to restore greenery to the failed site while preserving the beautiful landscape of Mt. Nantai, the symbol of Nikko.

Daiya River groundsill works



◀Past

Present ▶

This project dates back to the sabo project started in 1933 under the direct management of the national government. The project involved the construction of groundsill works, spur dikes and revetment works for preventing turbulence in the main river and the scouring of the embankment base.

Steady progress in the project in recent years has stabilized the river channel, enabling the river area to be partially used as a sediment control park for citizens' activities and as a space for recreation and relaxation, such as fishing. The 130 groundsill works are about 24 km long in total with the design riverbed gradient of 1/30 to 1/120.

●Environmentally friendly facility construction

Imaichi channel works with stone laid surface are gently sloped to allow easy access to the river.

Nirenoki-sawa groundsill work No. 1 has a wooden surface to ensure harmony with the surrounding landscape.

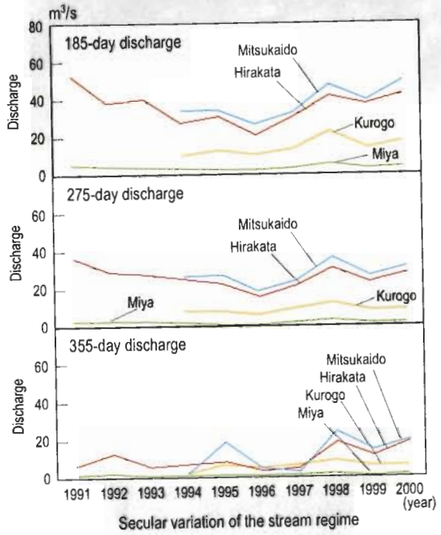
Supplying the Basin with Water

Use of Water the Kinu and Kokai Rivers

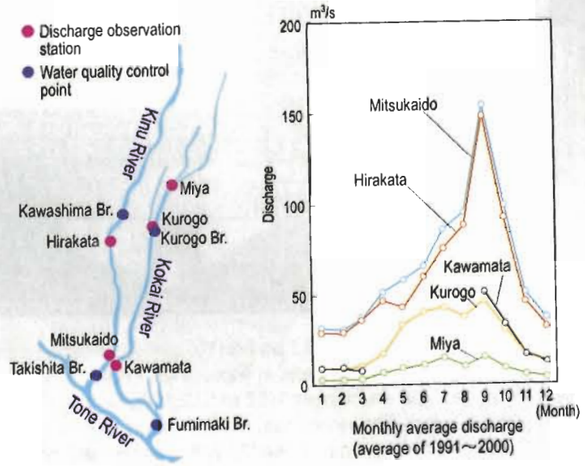
●Flow conditions and water quality

The Kinu River holds more than twice as much running water as the Kokai River. The annual total runoff recorded at the Hirakata and Mitsukaido points along the Kinu River is both 1.9 billion m^3, and that recorded at the Miya and Kurogo points along the Kokai River is 200 million m^3 and 700 million m^3 respectively.

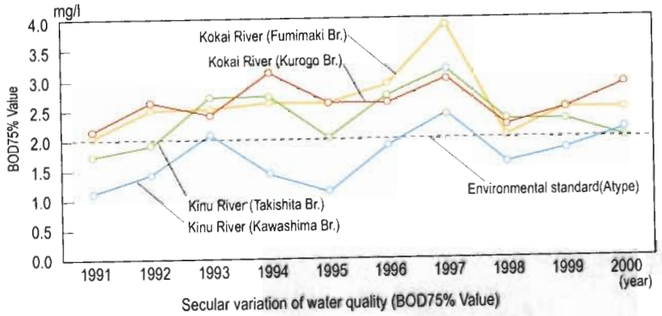
With regard to water quality, the BOD level at points except the Kawashima Bridge point on the Kinu River is above regulatory criteria, and further efforts are therefore required in the midstream and downstream areas.



Secular variation of the stream regime



Monthly average discharge (average of 1991～2000)



Secular variation of water quality (BOD75% Value)

●Use of water

The Kinu River water is mainly used for power generation in its upper reaches and for agriculture in its midstream and lower reaches. The water is also marginally used as municipal and industrial water. The Kokai River water, on the other hand, is almost entirely used for agriculture.

Agricultural water

The Kinu and Kokai Rivers supply irrigation water to paddy fields of about 40,000 ha in Tochigi and Ibaraki Prefectures.

	Irrigated area (ha)	Maximum water intake (m^3/s)
Kinu R.	25,699	103.48
Kokai R.	14,045	61.69
Total	39,744	165.17

Water for power generation

Along the Kinu River system, electric power is generated at 25 hydroelectric power stations including the Imaichi pumped storage power station.

	Maximum output (kW)	Maximum discharge (m^3/s)
Kinu R. (25 stations)	1,352,510	1104.5

Municipal water

Many areas depend upon groundwater for water supply. However, increased water demand accompanying urbanization and groundwater pumping restrictions introduced to prevent land subsidence have reduced the availability of water. A wide-area municipal water supply project is underway in both Tochigi and Ibaraki Prefectures.

	Cities, towns and villages served	Design maximum daily supply (m^3)
Kinu municipal water supply project	5	38,000
Haga Chubu Municipal Water Corporation	3	12,000
Wide-area municipal water supply project in west Ibaraki Prefecture	23	80,000
Municipal Water Corporation in south Ibaraki Prefecture	4	64,000

Industrial water

In Tochigi Prefecture, water from the Kawaji Dam is pumped from the Okamoto head works. In Ibaraki Prefecture, on the other hand, water is mainly drawn from Lake Kasumigaura, sent to the Kinu and Kokai Rivers.

Water source	Industrial complex and corporation using industrial water
Kinu R. (Kawaji Dam)	Kiyohara Industrial Complex and three other locations
Lake Kasumigaura (Kasumigaura canal)	Shimodate Daiichi Industrial Complex and six other locations

Hydroelectric Power Generation

●Prefecture advanced in terms of hydroelectric power generation

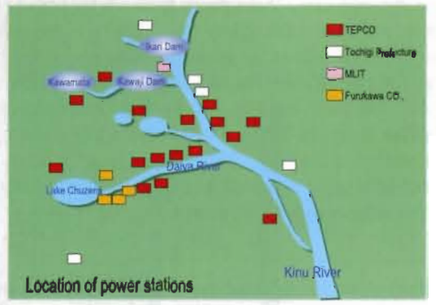
All the power stations in Tochigi Prefecture generate hydroelectric power. In 1893, the Mukogawara Power Station in Nikko City was the first power station to be constructed in the prefecture. This was the first electric utility that started business in the prefecture and the third in the country.

Along the Kinu River, the first power station was constructed in 1914, Shimotaki Power Station (presently the Kinugawa Power Station) in Kinugawa Onsen. The power station with an output of 43,500 kW was the largest in the East, and supplied power to the street railway system in Tokyo. The power station was impressive since it featured a large power generating capacity and long-distance power transmission.

Mukogawara power station

●Power generation facilities on the Kinu River

In the upstream Kinu River, 25 power stations are located including the Imaichi Power Station, the largest in Tochigi Prefecture, and the Kinugawa Power Station. They have a combined output of 1,352,510 kW.



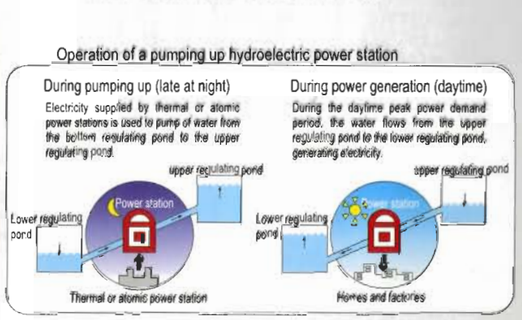
Location of power stations

Power stations of the Kinu River system

	Maximum output (kW)	Maximum amount of used water (m^3/s)
1. TEPCO (16 stations)	1,291,050	497.5
Kinugawa station	127,000	45.0
Imaichi station	1,050,000	240.0
Others	114,050	212.5
2. Tochigi prefecture (4 stations)	31,300	75.6
3. MLIT (1 station)	360	0.5
4. Furukawa CO.,LTD (4 stations)	29,800	33.4
Total (25 stations)	1,352,510	1,104.5

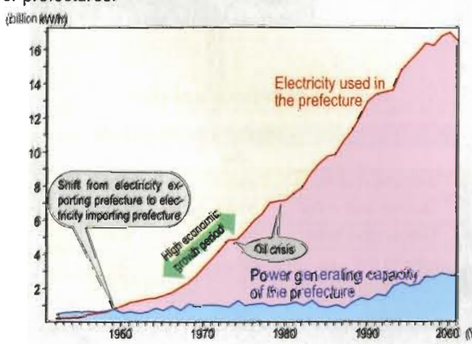
TEPCO : The Tokyo Electric Power Company, Incorporated
MLIT : Ministry of Land, Infrastructure and Transport

Operation of a pumping up hydroelectric power station



●Current power generation situation in Tochigi Prefecture

Tochigi Prefecture, once a leader in power source development using hydroelectric power, accounted for 13% of the national power generating capacity in the early Taisho Period (starting in 1912) and exported electricity to other prefectures. However, since 1959, the prefecture has been importing electricity from other prefectures.



Water for Irrigation

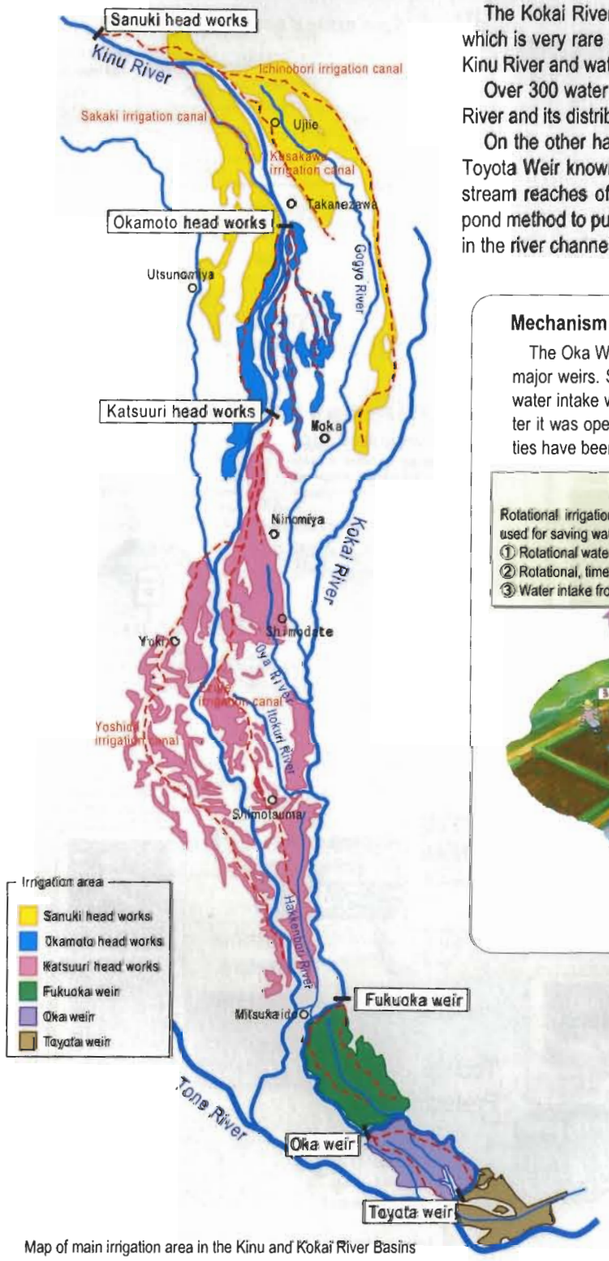
●Water of the Kinu and Kokai Rivers

In the past, many water intakes were used for the supply of agricultural water on the Kinu River. However, almost all midstream and downstream water intakes were reorganized into three weirs, which are used today.

The Sanuki head works located in the uppermost reaches were completed in 1966, to which nine irrigation canals including Ichinobori and Sakaki Irrigation Canal were connected. Water pumped from the head works is first used for prefectural power generation in Kazamiyamada, and then used for agriculture.

Next, the Katsuuri head works were constructed in 1976, to which five irrigation canals downstream of the Kinu River were integreted. The new irrigation canal, on the right bank, supplies water from the Ta River and on the left bank, recycles water returned from the upstream paddy fields using the Kurogo Weir on the Oya River.

Finally, the Okamoto head works were constructed in 1986 and went into operation the following year. The head works that represent the integration of the eight remaining weirs are designed to pump water to irrigate the farmland in the left bank districts of the Kinu River and to supply municipal and industrial water.



Map of main irrigation area in the Kinu and Kokai River Basins

The Kokai River is characterized by the large share of its paddy area in the basin, which is very rare case. These paddy fields are supported by irrigation water from the Kinu River and water returned from the 10,000 ha of paddy fields.

Over 300 water intakes for agricultural water supply are located on the main Kokai River and its distributaries. The area irrigated by these facilities totals some 24,000 ha.

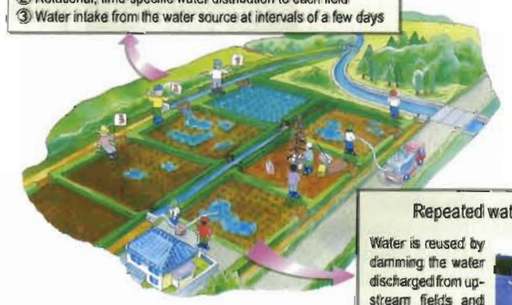
On the other hand, irrigation and drainage canals including the Fukuoka, Oka and Toyota Weir known as the three major weirs in Kanto were constructed in the downstream reaches of the Kokai River. These three weirs are well known for using the pond method to pump river water to a high elevation and store a large amount of water in the river channel as if storing water in a pond.

Mechanism for repeated use of water in the area around the Oka Weir

The Oka Weir has suffered from the most serious water shortage among the three major weirs. Since natural water intake can be continued only for a day and a half, water intake was intermittent; for example, the water intake was closed for a day after it was opened for a day and a half. To make up for such water shortages, facilities have been constructed that can repeatedly use the irrigation water.

Rotational irrigation

Rotational irrigation, a water distribution management method used for saving water, involves:
① Rotational water distribution to each irrigated area
② Rotational, time-specific water distribution to each field
③ Water intake from the water source at intervals of a few days



Repeated water use

Water is reused by damming the water discharged from upstream fields and by pumping the discharge.

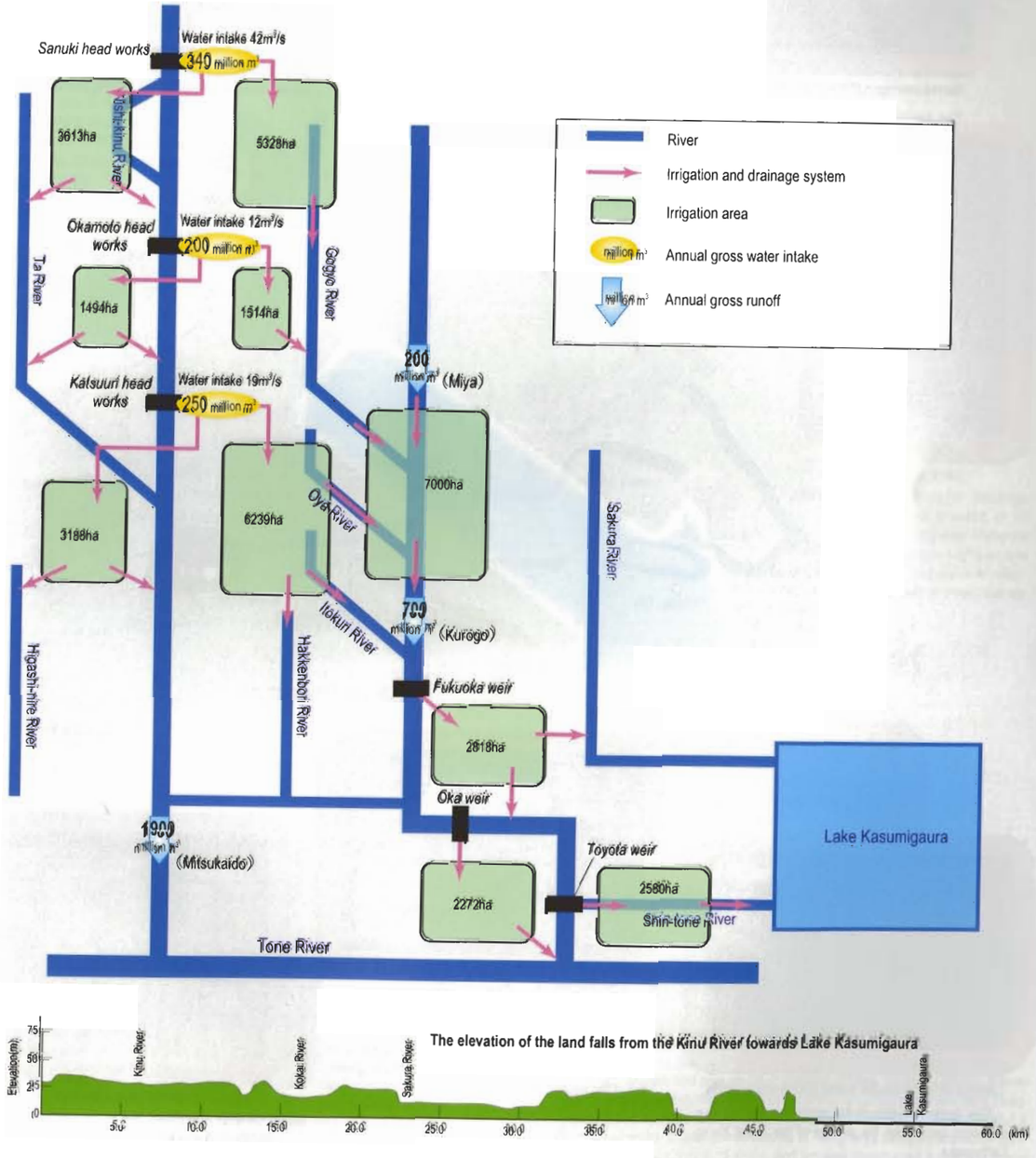
Irrigation area and Maximum water intake

	Irrigation area (ha)	Maximum water intake (m^3/s)
Sanuki head works	8940.9	42.00
Okamoto head works	3008.0	12.20
Katsuuri head works	9427.8	18.95
Fukuoka weir	2617.9	13.6
Oka weir	2272.0	9.2
Toyota weir	2580.0	9.5

●Water flow in usual times

In usual times, water is first taken in at the Sanuki head works on the Kinu River. Then, the 60% of the water that is discharged to the left bank districts enters the Kokai River system for various uses, and finally is drawn into the water intake on the Sakura River and those at the three weirs in the downstream reaches of the Kokai River. A fraction of the 50% of the water taken in at the Okamoto head works that is discharged to the left bank districts and almost 70% of the water taken in at the Katsuuri head works that is discharged to the left bank districts enters the Kokai River and is finally drawn into the water intake on the Sakura River or pumped into three weirs in the downstream reaches of the Kokai River. Water intake at the three head works on the Kinu River (the average between 1994 and 2002) was a total of 1.17 billion m3 a year. The amount of water used on the left bank when divided by the irrigation area is 700 million m^3 a year. This amount of water is repeatedly used and provides a water source for irrigating the Kokai River Basin through the Gogyo, Oya, Itokuri, Hakkenbori and other rivers.

A large part of water drained from the Kinu and Kokai Rivers enters Lake Kasumigaura and only a fraction of water drained from the right bank of the Kinu River and from the Oka Weir on the Kokai River returns to the Tone River.



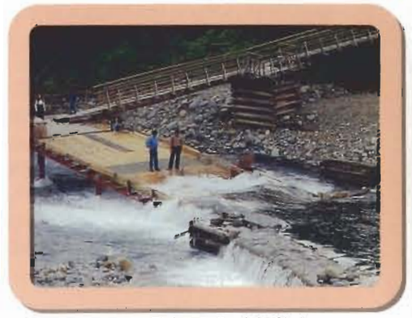
Environment and Culture of the Kinu and Kokai Rivers

Sacred palanquin (Shimodate City)

This tradition of carrying a sacred palanquin, which was inaugurated to commemorate the victory of the Sin-Japanese War in 1895, is rooted in the ancient purification practices carried out to cleanse sins and impurity in the river. The sacred palanquin used for the festival is the largest in Japan.

Summer festival (Moka City)

Moka City hosts a 3-day summer festival, during which sacred palanquins and floats are carried through the city, the sacred palanquins are carried across rivers and floats are dashed against each other.



Fish trap (Imaichi City)

Fish traps are placed in the Kinu River to trap sweetfish and other fishes that come down the river. Fresh sweetfish broiled with salt are a delicacy during the fishing season.

Lantern-offering on the water (Shimodate City)

This lantern-offering on the water was started as a memorial service for the victims of the Great Kanto Earthquake.

Cherry banks

The construction of cherry banks, which involves landfilling the river bank and planting cherry trees, is being carried out along the Kinu and Kokai Rivers in order to reinforce the embankment and promote greening of the aquatic environment.

Water wheel (Imaichi City)

Imaichi City ranks first in the production of cedar incense. In olden days, water wheels driven by agricultural water were used to grind incense powder.

Kegon-no-taki Waterfalls

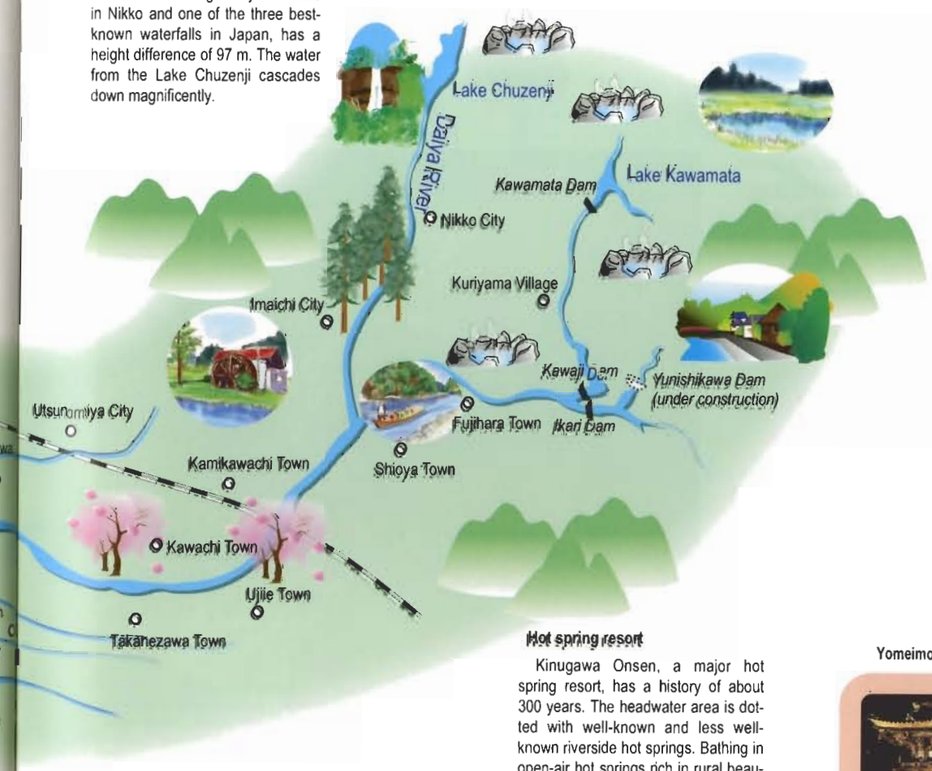
The Kegon-no-taki Waterfalls, best known among many waterfalls in Nikko and one of the three best-known waterfalls in Japan, has a height difference of 97 m. The water from the Lake Chuzenji cascades down magnificently.

Community of Heike fugitives

Tradition has it that the community in Yunishikawa was settled by Heike fugitives.

The Kinunuma Marsh

The Kinunuma Marsh, a plateau marsh located at an elevation of about 2,000m surrounded by Mt.Kinunuma and Mt.Monomi, it is said to be the highest plateau marsh in Japan.



Rows of Cedars in Nikko

More than 200,000 cedar seedlings have been planted over a period of 20 years along the Nikko Highway, Reiheishi Highway, and the Aizu-Nishi Highway, and more than 13,000 of these are now maturing. The remaining rows of trees now extend about 35.41 km.

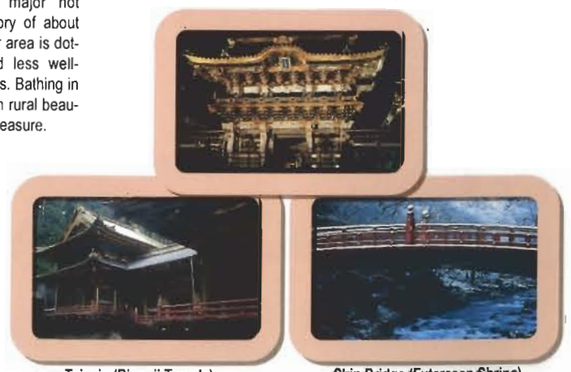
Downstream tour of the Kinu River

The 6-km tour down the Kinu River from Kinugawa Onsen to Otoro allows passengers to enjoy the beauty of natural valleys.

Hot spring resort

Kinugawa Onsen, a major hot spring resort, has a history of about 300 years. The headwater area is dotted with well-known and less well-known riverside hot springs. Bathing in open-air hot springs rich in rural beauty is a simple, wonderful pleasure.

Yomeimon Gate (Toshogu Shrine)



Taiyuin (Rinnoji Temple)

Shin Bridge (Futarasan Shrine)

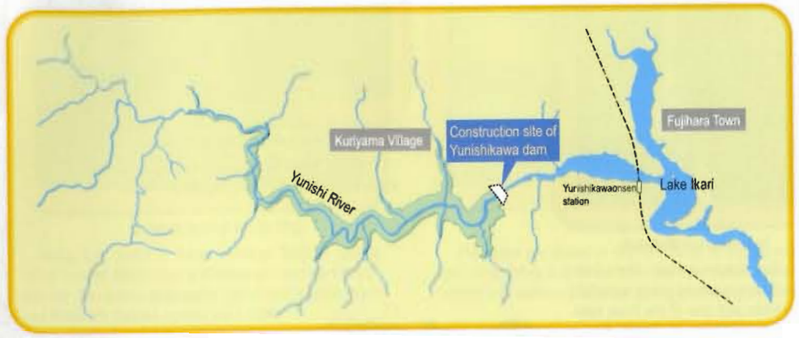
The two temples and one shrine (Futarasan Shrine, Toshogu Shrine, Rinnoji Temple) located at Nikko and the historical artifacts surrounding them were designated a World Heritage Site in 1999. Toshogu and Taiyuin that are the center of the group of shrine and temple structures of Nikko were designed based on mausoleum architecture typical of shrine and temples constructed in the late feudal period (1600-1867).

The Future

Construction of the Yunishikawa Dam

●Yunishikawa Dam

At present, demand for water is accelerating due to urbanization and changes in people's lifestyle in the downstream Tone River Basin including the Kinu River Basin. The Yunishikawa Dam is scheduled to be newly constructed as the fourth dam in the upstream Kinu River in order to respond to water demand and protect the river basin from flood damage.



●Role of the Yunishikawa Dam

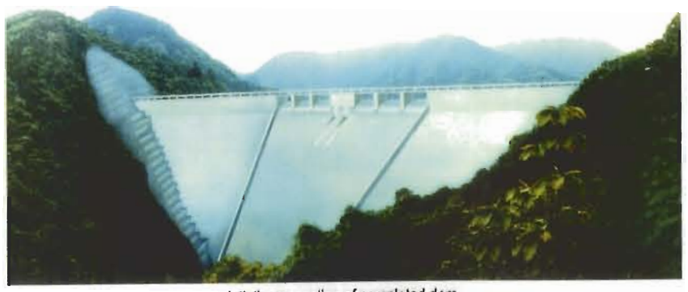
The Yunishikawa Dam was designed to regulate the water flow to prevent a large amount of water from flowing downstream at a time, thus reducing flood damage in the downstream Kinu and main Tone Rivers.

Even during water shortages, the discharge of water from the dam helps stabilize the water flow downstream of the Ikari Dam and along the main Tone River.

Planned dam construction location

Specifications of the Yunishikawa

Location	Nishikawa, Kuriyama Village, Shioya country, Tochigi Prefecture
Type of dam	Concrete gravity dam
Dam hight	130.0m
Crest length	392.0m
Catchment area	102.0km^2
Ponding area	2.86km^2
Gross storage volume	99 million m^3
Effective storage volume	96 million m^3
length of the main river channel	22.5km^2



Artist's conception of completed dam

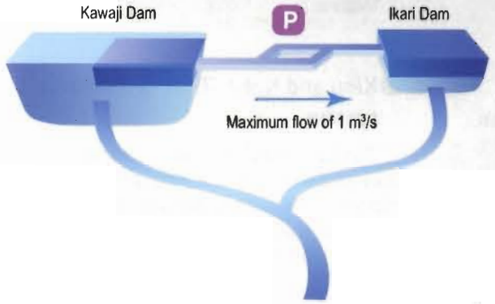
Thanks to the completion of the Yunishikawa Dam, water supply will become more stable. The dam is scheduled to supply not only agricultural water but also municipal water to Utsunomiya City, Ibaraki Prefecture and Chiba Prefecture.

Efficient Use of Existing Dams

●Collaboration project involving a group of upstream dams on the Kinu River

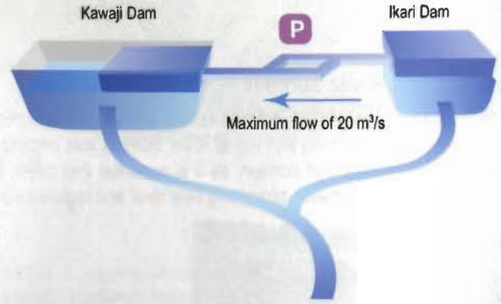
The linking of two dams with different water storing capacities enables the effective use of precious water resources and improves water flow in the Ojika River and main Kinu River downstream of the Ikari Dam. This collaboration project involving a group of upstream dams on the Kinu River ensures sufficient river flow and stable water supply.

- Kawaji Dam and Ikari Dam during the season of low rainfall -



The Kawaji Dam supplies stored water that originally came from the Ikari Dam in order to improve water flow. The Ikari Dam discharges water in order to improve water flow immediately downstream of the dam and in the main Kinu River. Meanwhile, the Kawaji Dam discharges stored water that originally came from the Ikari Dam when water flow drops low immediately downstream of the Ikari Dam and downstream of Sanuki on the Kinu River.

- Kawaji Dam and Ikari Dam during the season of high rainfall -



The Kawaji Dam can store water using the remaining capacity. The Ikari Dam pumps out water that cannot be stored to the Kawaji Dam. Water inflow to the Ikari Dam when it has been filled to maximum capacity is led to the Kawaji Dam at up to 20 m^3/s if the Kawaji Dam has storage capacity remaining.

●Large-scale facility improvement project

At present, the Ikari Dam, which is only operated on an open or close basis, has a water discharge capacity of about 100 m^3/s, making it difficult to adjust the water level in the dam reservoir and causing problems including a rapid rise in the downstream water level during water discharge. An improvement work was therefore planned with the objective of installing a new discharge facility with the discharge capacity of 500 m^3/s.

The work specifically involved the drilling of two holes in the dam body to install discharge pipes and the installation of a water discharge gate that can be opened partially to prevent a rapid rise in the downstream water level.

Image of discharge facility

River Improvement based on Resident Participation

●Development of the river area environment

Through the joint effort of municipalities and local volunteers up to 2001, flower belts of about 11 km in total length have been planted in 27 locations in five cities, nine towns and two villages in the Kinu and Kokai River Basins. The flower belts provide opportunities for various events as well as for recreation and relaxation.

Milestones are set up as reinforcement to the levee using landfill outside the levee, to stockpile sediment for flood control and as the center for flood control activities. As of FY2001, milestones have been set up in 17 locations along the Kinu River and 10 locations along the Kokai River.

Flower belt

Milestone

●Kinu and Kokai River Summit

Typhoon No. 10 in August 1986 inflicted severe damage to the Kokai River Basin. After the flood damage, the Kinu and Kokai River Summit was organized to develop a basin that ensures safety and comfort, as it is essential that cities, towns and villages in the basin work together in promoting new river and regional development.

Rafting

Kinu and Kokai Rivers cleaning mission

●Kinu and Kokai River coordinator system

The Kinu and Kokai River coordinator system was created during the Kinu and Kokai River Summit in 2002. This system is designed to promote river improvement activities based on community participation.

●Kokai River Adoption Program

The Kokai River Adoption Program is designed to promote community involvement in the management of rivers for the purpose of beatifying the environment. This system, the first attempt of this kind in the Kanto region, involves river protection activities through the joint effort of the residents and municipalities in the Kokai River basin and the Shimodate Office of the Kanto Regional Development Bureau of the Ministry of Land, Infrastructure and Transport.

●Tree planting on Mt. Nantai

As a part of their general education, children participate in tree planting activities to show them that protecting nature also protects human lives and preserves their way of life. Additionally, they are taught about the Nikko Sediment Control Project.

Children planting trees

●Upstream-downstream communication

The Upstream Downstream Communication Project is implemented to use water to deepen mutual understanding between the people of the upstream water resource region and those living in the downstream region that benefit from the water.

Upstream-downstream communication

Risk Management and Advanced Use of Information

●River disaster prevention stations

The river disaster prevention stations were set up for risk management and information sharing. At present, these stations are located in the Moka district in the Kinu River Basin and the Fujishiro district in the Kokai River Basin.

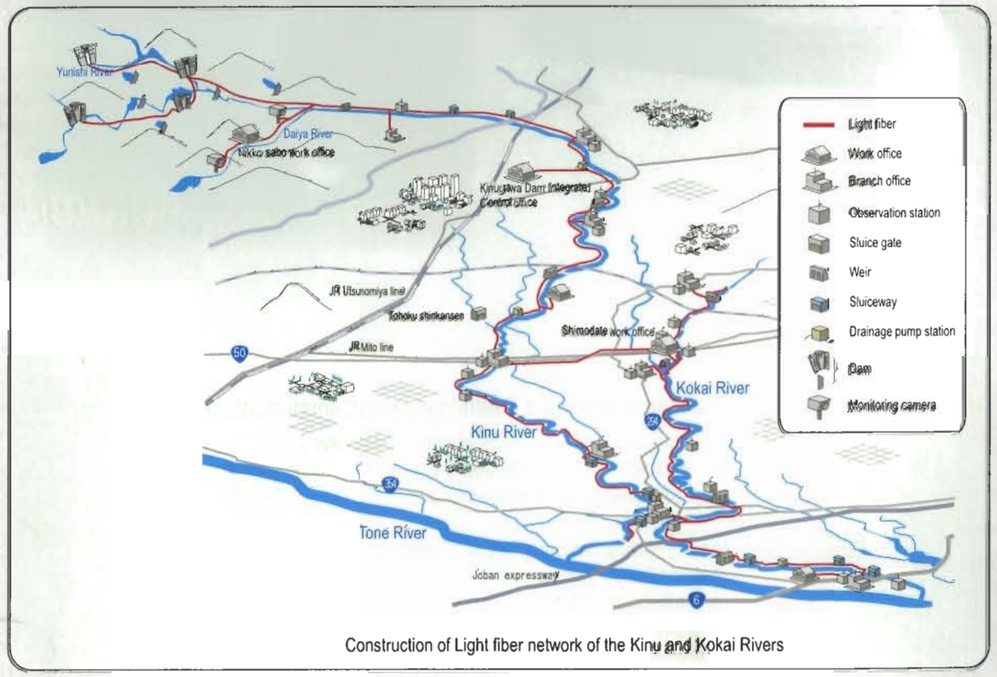
These stations normally serve as the center of river patrols and can be used for recreational purposes by local residents. During flooding, these stations also function as the center of activities to protect important facilities such as levees using the heliport, flood fighting yard and stockpiled materials, and are used as emergency evacuation sites.

The Kinu River Moka district disaster prevention station

The Kokai River Fujishiro district disaster prevention station

●Information management

The wide-area Kanto information network project was established in order to prevent disasters and carry out risk management in the Kanto region and promote regional development through collaboration between the Kanto Regional Development Bureau of the Ministry of Land, Infrastructure and Transport and 11 prefectures and ordinance-designated cities. The project involves the construction of a 5,500-km optical fiber network by 2005 to share information with organizations concerned and the use of various media to increase the efficiency of information provision to citizens.



Construction of Light fiber network of the Kinu and Kokai Rivers