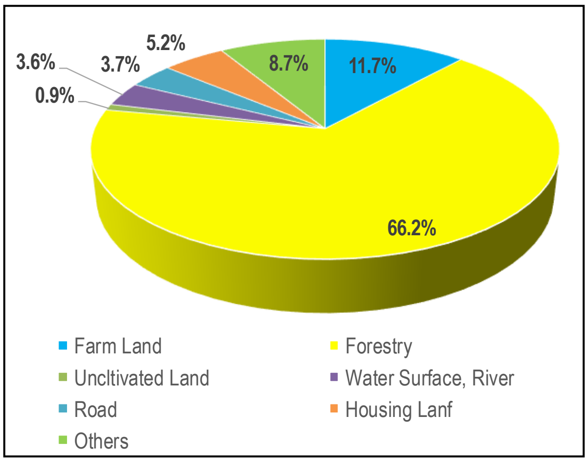
Reference Document

1. Overview of Japan

1.1 Land

Japan is an archipelago extending from north to south, with a land area of approximately 378,000 km^2 spread across the subarctic and subtropical zones. The vast majority of Japan's land area is mountainous, with forests occupying approximately two-thirds of the country's land. The mountainous terrain is rugged, and only 30% of the land area is inhabitable (Figure 1.1).



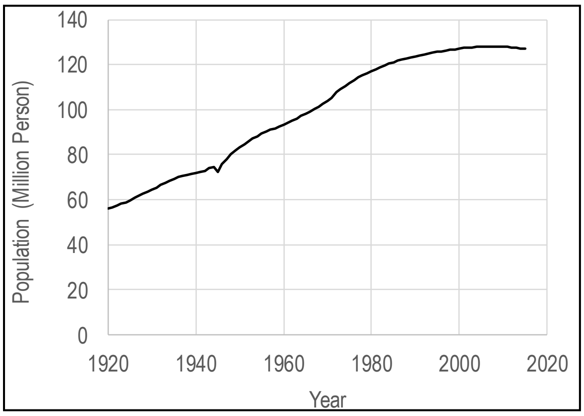
Source: Ministry of Land, Infrastructure, Transport and Tourism

Figure 1.1 Land Use in Japan

1.2 Population

Japan's current population is estimated at 126,127 thousand (October 2019), and Figure 1.2 shows the population trend. Japan's population peaked at 128 million in 2008 and has been on a downward trend since then. Approximately 50% of Japan's total population lives within 50 km of the urban centers of Tokyo, Nagoya, and Osaka (located in the alluvial plain) (approximately 6% of the total land area).

In addition, due to aging, the average life expectancy of Japanese people is currently estimated at 81.25 years for men and 87.32 years for women (2018).[1]



Source: Statistics Bureau

Figure 1.2 Trends in Japan's Total Population

1.3 Precipitation

Japan is located on the eastern edge of the Asian Monsoon region, one of the world's heaviest rainfall areas recording annual average precipitation of 1,668 mm (average from1986 to 2015), which is about 1.6 times higher than the world (land area) average annual precipitation of about 1,065 mm, according to the Food and Agriculture Organization's (FAO) AQUASTAT database. The annual average precipitation in each region is shown in Table 1.1. The precipitation and temperature at various locations in Japan are shown in Figure 1.3.

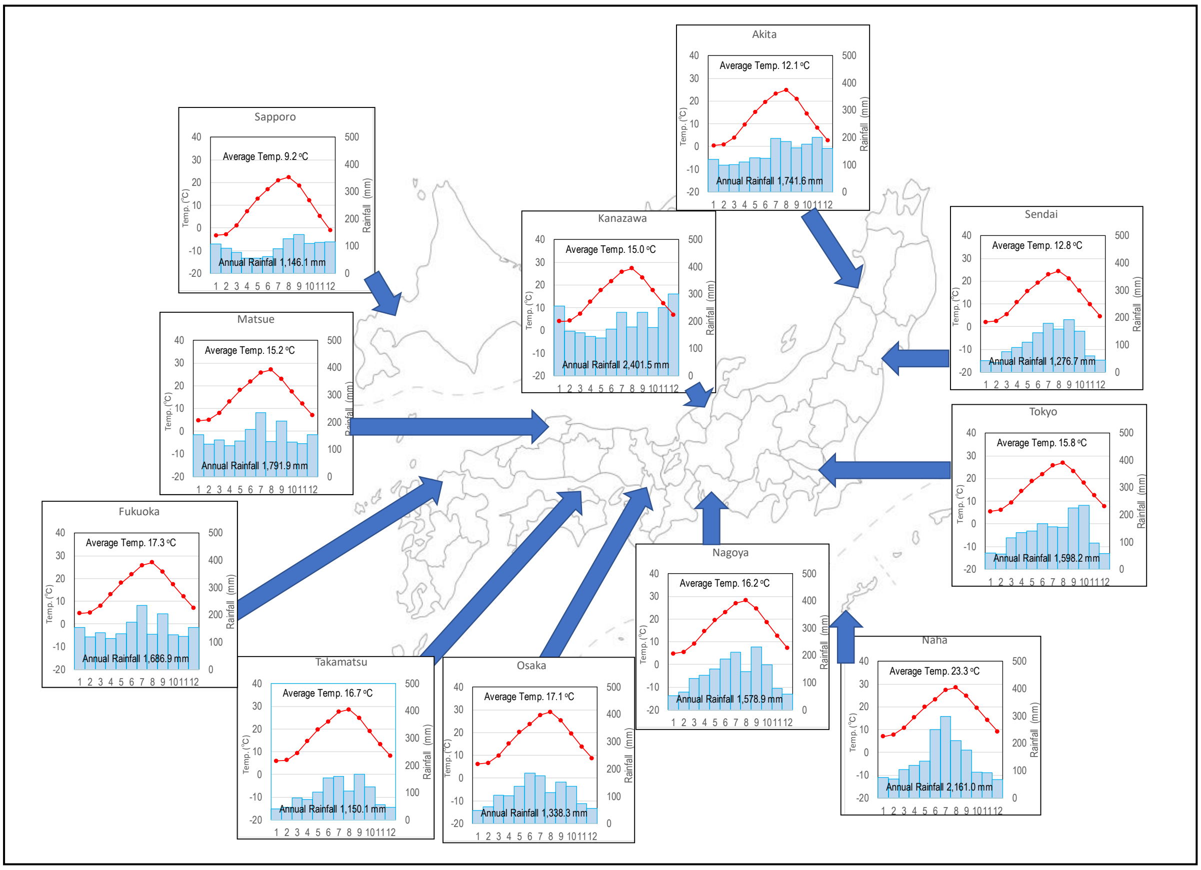
[1] Ministry of Health, Labor and Welfare, Simplified Life Tables.

Table 1.1 Annual Average Precipitation by Region

(Unit : mm/year)

Region	Precipitation	Region	Precipitation	Region	Precipitation
Hokkaido	1,148	Hokuriku	2,333	Kyusyu	2,299
Tohoku	1,652	Kinki	1,791	Okinawa	2,086
Kanto	1,608	Chugoku	1,694		
Tokai	2,037	Shikoku	2,202		

Source: 2019: Current Status of Water Resources in Japan, MILT



Source: Prepared by Project Research Team based on Data from Japan Meteorological Agency

Figure 1.3 Monthly Precipitation and Temperature in Japan

1.4 Water Resource Potential

Japan's water resource potential is approximately 420 billion m^3/year (average from 1986 to 2015: "average water resource potential"). During periods of low rainfall, which occurs approximately once every 10 years, the water resource potential is approximately 290 billion m^3 (drought year water resource potential), or 69% of the average water resource potential.

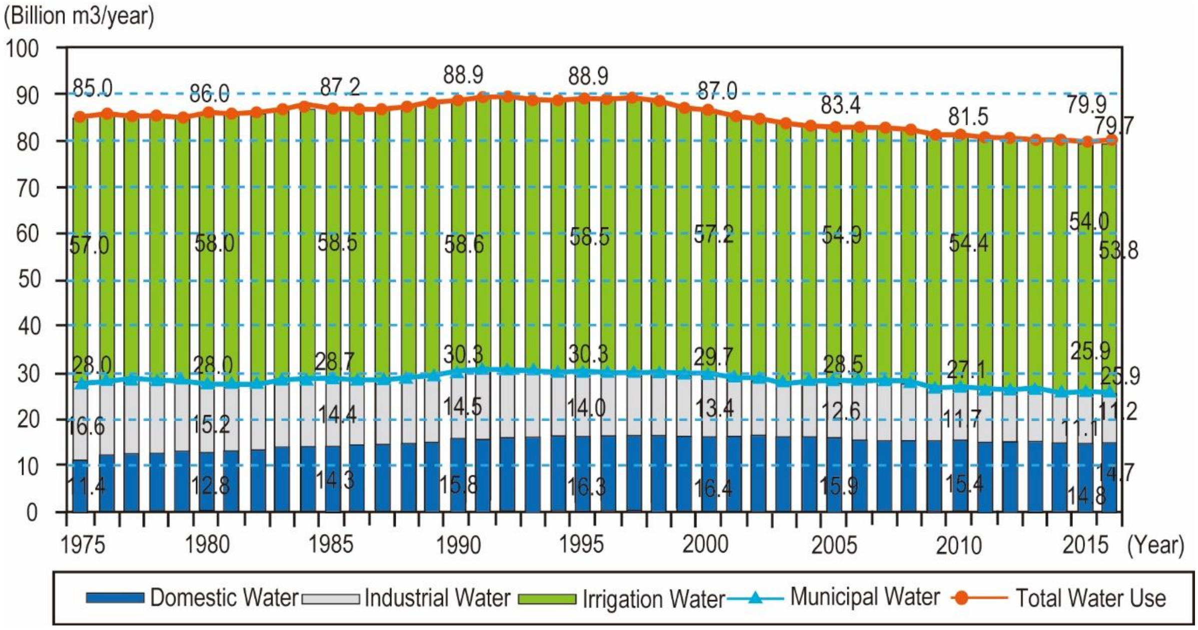
The ratio of drought-year water resources potential to average water resources is lower in the Kinki, Sanyo, Shikoku, Kyushu, and Okinawa regions and larger in the Hokkaido, Tohoku, Kanto, Tokai, Hokuriku, and Sanin regions. Water resource potential per person is lower in the Kanto Coastal Area, Kinki Inland Area, Kinki Coastal Area, Sanyo, Kitakyushu, and Okinawa than entire Japan, and larger in Hokkaido, Tohoku, Tokai, Hokuriku, Sanin, Shikoku, and Southern Kyushu.

According to FAO AQUASTAT data, water resources potential per person in Japan is about 3,400 m^3/person/year, which is less than half the world average of approximately 7,300 m^3/person/year.

1.5 Water Use and Government Agencies

In 2016, nationwide water use (on an abstraction basis) was 80 billion m^3/year, with urban water use at approximately 25.9 billion m^3/year and irrigation water use at approximately 53.8 billion m^3/year. Figure 1.4 shows the water use trends in Japan.

Table-1.2 shows the relevant administrative agencies for these water uses.



Note: 1. Preparation by Water Resources Department, Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
2. This value is based on the amount of water intake, as estimated by the Water Resources Department, and includes the amount of water returned to rivers after use.
3. Industrial water is the amount of fresh water supplied to factories with four or more employees. However, this does not include water used in public utilities.
4. For agricultural water, the values for 1981–1982 are 1980 estimates, values for 1984–1988 are 1983 estimates, and values for 1990–1993 are 1989 estimates.
5. Sometimes the totals do not add up due to rounding.

Source: 2019: Current Status of Water Resources in Japan, MILT

Figure 1.4 Water Use Trends

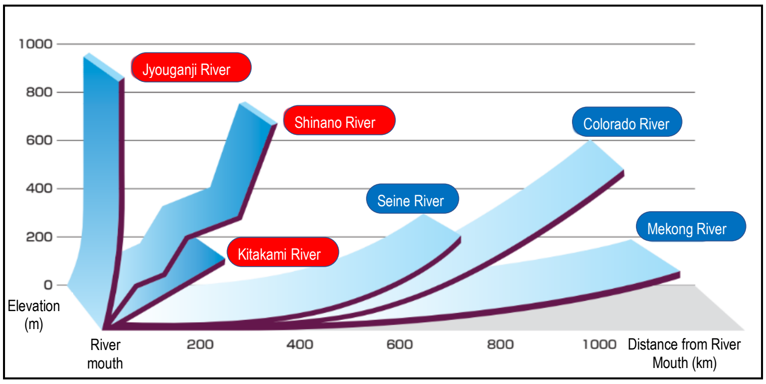
Table 1.2 Water Use and Government Agencies

	Tap Water	Industrial Water	Irrigation Water	Power Generation
National Level	Ministry of Health, Labor, and Welfare	Ministry of Economy, Trade, and Industry	Ministry of Agriculture, Forestry and Fisheries	Ministry of Economy, Trade, and Industry
Prefecture Level	Water supply business to municipalities may be conducted	Implemented industrial water supply project		
City, Town, and Village Level	Implemented a project to supply water to each household			
			Farmers associations manage water supply	

Note: If the water supply source is a river, the user must obtain permission from the river administrator.
Source: Project Research Team

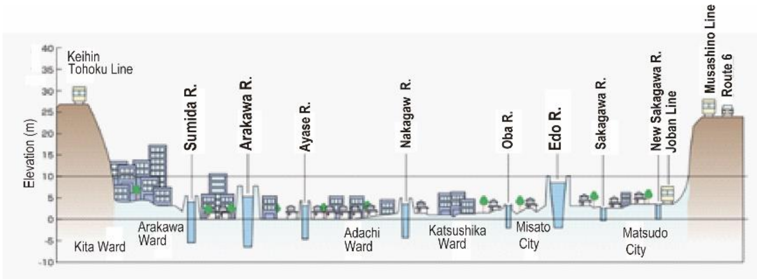
1.6 River

Japan is an island nation with a few plains and several steep mountainous areas, and the country is narrowly divided by a series of small rivers. The Tone River, the largest river in Japan, has a basin area of 16,840 km^2 and accounts for only 4.5% of the total land area. In Japan, only four rivers (Tone, Shinano, Ishikari, and Kitakami) have a basin area of more than 10,000 km.[2]



Source: Ministry of Infrastructure, Land, Transportation, and Tourism

Figure 1.5 River Slope



Source: Ministry of Land, Infrastructure, Transportation, and Tourism

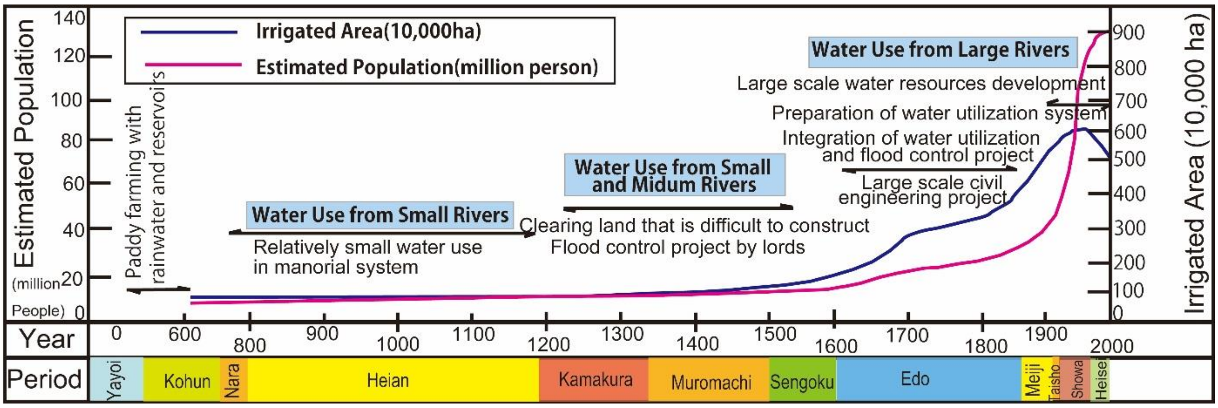
Figure 1.6 Location of the Edogawa, Arakawa, and Sumida Rivers in Tokyo

Comparing the longitudinal slope of rivers, the longitudinal slope of Japanese rivers is steeper than that of continental rivers (Figure 1.5). This is due to active localized rising and sedimentation caused by orogenic movement, similar to rivers on islands and peninsulas of the Asia-Pacific. The major rivers in Asia, such as the Yangtze, Ganges, Indus, and Mekong Rivers, also have steep gradients because of the steep mountainous terrain caused by orogenic movements in the upper reaches, but the gradient from the origin to the river mouth is extremely gentle owing to the wide alluvial plains formed in the middle and lower reaches by the confluence of many branch rivers. Rivers in Japan are similar to the upstream branches of continental rivers, and river water flows immediately into the sea. Therefore, the scale of the alluvial plain is small, and the river becomes a rapid stream. As the population and assets are concentrated in the alluvial plain formed in the middle and lower reaches of the river, flood protection measures are extremely important because once a flood occurs, the destructive power of the river is high and flood damage is enormous. As shown in Figure 1.6, many rivers in Tokyo flow at elevations higher than the city center, which tends to increase the damage caused by flooding.

2. History of Water Resources Development and Management in Japan

2.1 Ancient Times

Paddy rice, the staple food of Japan, was introduced via tropical Asia during the early Yayoi period (around the 3rd century BC). Rice cultivation is believed to have spread gradually northeastward from Kyushu and across all regions. Paddy fields have been chosen for wetlands in the lower reaches of rivers, coastal sandbars, and deltas. However, to protect paddy fields from flooding and to increase crop yields as much as possible, people have to rely on flood protection and water utilization technology. With the spread of rice cultivation, paddy fields have been developed in various areas, and civil engineering technologies for flood protection and water utilization have gradually developed. Figure 2.1 shows the changes in population, irrigated area, and water use.



Source: Partial excerpt and revision of Farmland and Water in Japan Ministry of Agriculture, Forestry, and Fisheries

Figure 2.1 Changes in Population and Cultivated Area

Japan's first recorded water resource development project[2]

In Kadoma City, Osaka Prefecture, Manda Levee is believed to be the first recorded river improvement work in Japan. Emperor Nintoku established the capital at Namba in 313 CE, after which Yodo River improvement works began. According to the Chronicles of Japan, during the 11th year of Emperor Nintoku's reign, the Manda Levee (flood control project) was constructed at the end of the Yodo River, and excavation works of the Namba no Horie (present Tenma River) began. The Namba no Horie was constructed to prevent riverbed aggradation and drainage improvement of farmland areas by preventing sediment inflow from upstream regions.

2.2 Yamato Period (4th century to early 8th century)

During the Yamato period, continental culture (Chinese culture) was introduced along with Buddhism, and irrigation water use technologies, such as ponds, were brought from the continent, and this initiated the development of civil engineering technology in Japan. During the Sui and Tang Dynasty (618–907

[2] History of Modern Japanese Civil Engineering, Second Edition, Takahashi Hirosi

CE), monks who traveled to the continent (present-day China) to study brought not only Buddhism but also continental culture and civil engineering technology directly to Japan.

Performance of Gyoki

Gyoki (668–749 CE), a Japanese Buddhist priest of the Nara period, built flood protection facilities and ponds to secure water in the Kinki region. Gyoki's projects were implemented by a large number of civilians (Gyoki's group) called the Aribasho, who sympathized with Gyoki's desire to execute projects to save people in need.

Irrigation ponds that remain today are the Kumeda, Sayama, and Konyo. A spillway and levee were constructed around 730 CE to prevent floods from entering arable lands on the left bank of the middle and lower reaches of the Yodo River further downstream.

In addition to Gyoki, Kukai, a monk who studied in China, also implemented civil engineering projects in various areas, mainly irrigation ponds, including the Mannoike Pond.

2.3 Heian Era to Muromachi Era (Early 9th Century–Late 15th Century)

Civil engineering began to decline in Japan around the 9th century, peaking during the 10th century and continuing into the 11th century, when there was a blank period for civil engineering projects. The reason for this decline is attributable to decentralized government power, and it became difficult to execute large-scale civil engineering projects because of the change in agricultural land development from the Ritsuryo system to the manorial system, and no new power emerged even though the ruling class lost power during the late Heian period, when monks executed civil engineering projects.

2.4 Warring States Era: Azuchi–Momoyama Era (16th Century)

The distinguished warlords during the Warring States period—a period marked by civil war and social upheaval were leaders of civil engineering projects. First, they responded to the expectations of their subordinates by constructing civil engineering projects in their respective territories and understanding them was the foundation for the surviving warring states. Flood protection projects have been conducted to protect farmland. Warlords, famous for their civil engineering projects, are listed below:

- Takeda Shingen (Kofu City area): The Kamanashi River and its tributaries, which are violent rivers, frequently flood the Kofu area. In response, the waterways were stabilized, and the momentum of the water was controlled. Levees (Shingen-tsutsumi) were built to protect against small-and medium-scale flood risks, while hazy levees were built to allow floodwaters to overflow during large-scale floods and return to the river afterward. Consequently, agricultural damage in the Kofu area was reduced.
- Sasa Narimasa (Toyama City and surrounding areas): Major floods occurred at a point called Mazeguchi on the Joganji River. At this point, a levee (Sasa levee) was constructed to change the direction of the river flow, which later reduced flood damage.

- Kato Kiyomasa (Kumamoto City area): Kumamoto City was prone to flooding because of the three rivers flowing in the area. Flood damage was reduced in Kumamoto City by straightening the Shirakawa River and connecting the Tsuboi River to the Iseri River through the inner moat of the castle. Weirs and irrigation channels were constructed for irrigation.
- Narutomi Hyogo (Saga Prefecture): The Chikuri Levee (hazy levee) was constructed on the Chikugo River to reduce flood damage on the Chikushi plain further downstream.

Flood protection strategies were carefully developed considering the characteristics of each river, and individual flood protection technologies, such as levees, were developed. Several flood protection structures were developed in each area during this period.

2.5 Early Modern Period (Edo Era) (early 17th century to late 19th century)

During the Edo era (1603–1868)—a period of peace with no civil wars for approximately 270 years—the country steadily accumulated social capital through various civil engineering projects. Civil engineering projects focused on flood protection, agricultural water utilization projects, and land reclamation projects to expand agricultural productivity. During this period, the farmland area increased from approximately 15,000 km^2 at the beginning of the Edo era to approximately 33,000 km^2 by the end of the period.

In the early Edo era, public water supply projects were implemented in many cities. Especially, during the Edo period (present-day Tokyo), when the population was rapidly increasing, water demand could not be covered by water supply from springs and wells. The first public water supply project in Japan was the Kanda waterworks. During that period, many public waters supply systems were constructed for irrigation purposes in local cities.

2.6 Meiji Era and before World War II (late 19th century to early 20th century)

(1) Meiji Era

Although the Edo era was closed to the rest of the world following a prolonged period of national isolation, Christian civilization had a considerable influence on Japan from the Warring States period to the early Edo era. Even during the period of national isolation, Japan was exposed to the influence of Western civilization through Dejima in Nagasaki. The Japanese had mere desk knowledge of Western technology and industry, however, with the advent of a new era, it was only natural for Japan to attempt to fully adopt modern science and technology. The national government hired a large number of foreign engineers to teach science and technology and train the Japanese people.

In the early Meiji era, adoption of most modern technology was dependent on foreign engineers; however, by the mid–1880s, Japanese students who had studied in Europe and the United States began to return to Japan, and Japanese engineers trained by foreign engineers began to appear on the scene. Foreign engineers could implement many technological activities.

During the early Meiji era, low-water channel works on rivers were an important measure to maintain river routes for boat traffic and drainage systems for irrigation. The Japanese government hired a Dutch engineer Van Doorn, who taught the importance of regularly observing river water levels and installing water level markers. Water levels were mainly observed using water level markers, but in a magazine published in 1890, there was a record regarding the use of a self-registering water level measuring device at Niigata on the Shinano River. In 1881, a self-registering tide gauge imported from the Netherlands was installed on the Kiso River. It is conceivable that the water level observation system has improved since the mid-Meiji era.

In the context of meteorological observations, in June 1875, Joynell conducted regular observations thrice a day, and the Tokyo Meteorological Monthly Report and Annual Report were published in 1876. The importance of meteorological and hydrological observations has been passed on from that period to the present.

Under the national government, the River Law was enacted in 1896, and the Ministry of Home Affairs[3] promoted flood protection projects, such as levee embankments, dredging, and floodway construction, on important rivers throughout Japan. According to the River Law, the governor of each prefecture was the river administrator. (However, since the governor was elected by the national government, the law actually reflected the will of the national government), and land within the river area was considered public land.

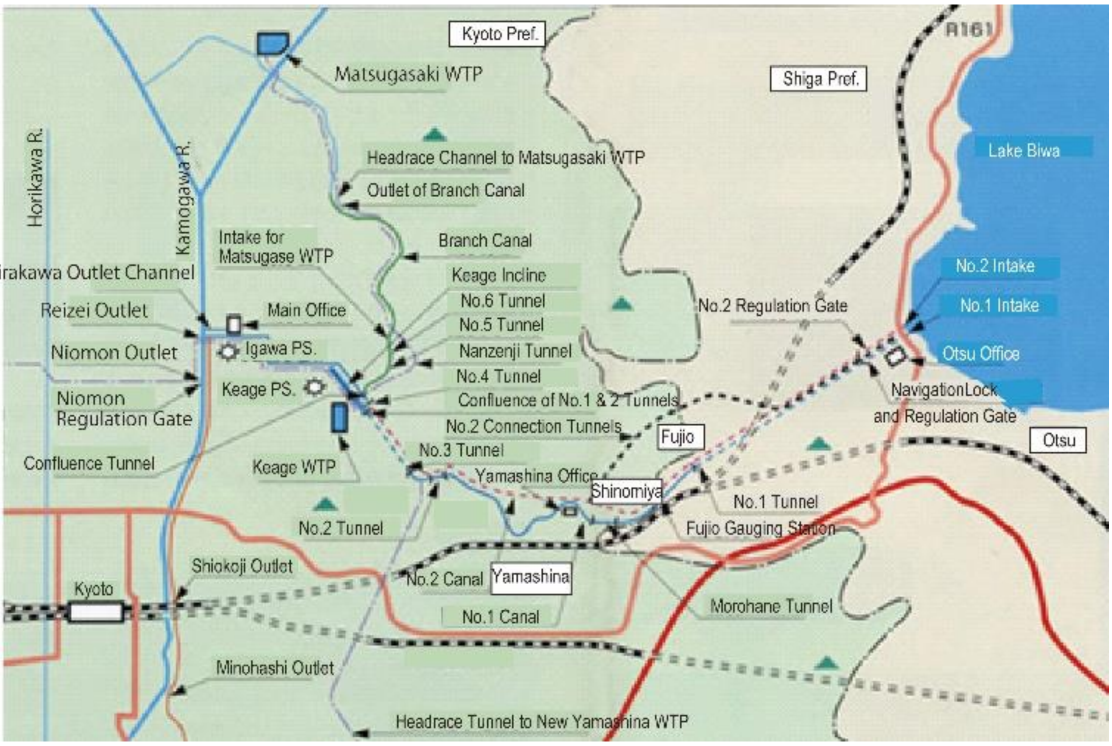
In the case of water rights, used irrigation water was recognized as a traditional water right. As for new water users, water supply, and power generation, it was difficult to acquire new water rights due to a lack of surplus water.

The Lake Biwa Canal project was introduced as a water resources-related project during this period.

Lake Biwa Canal Project

In 1881, to restore Kyoto, which had been declining with the capital being relocated to Tokyo, the governor of Kyoto Prefecture, Hokuto Kitagaki, decided to develop the Lake Biwa Canal as the most effective way to promote industry. It was a comprehensive development project comprising a multipurpose project for irrigation, water supply, industrial water supply, shipping, and hydroelectric power generation. This project was the first major civil engineering project in Japan that was implemented entirely by Japanese engineers, with Sakuro Tanabe as the chief engineer.

[3] During the era of the Imperial Constitution, the Japanese administrative body was responsible for domestic and civil affairs. After the war, it was dismantled and abolished by order of the General Headquarters (GHQ).



Source: 100-year Vision for society and Civil Engineering: Opening up all boundaries and laying the foundation for a sustainable society - Japan Society of Civil Engineers, Website of Lake Biwa Canal Memorial Museum
Location map: Website of Kyoto City Water Supply and Sewerage Bureau

(2) Taisho Era until the pre-World War II period

A major policy for flood protection was established during the Meiji era, and some large projects were steadily promoted across major rivers. The Okozu diversion project was introduced as a representative project.

Okozu Diversion Project

The Okozu Diversion Project is a 10-km-long man-made waterway that runs from Okozu—where the Shinano River comes closest to the Sea of Japan—to the Teradomari coast, where the floodwaters of the Shinano River flow into the Sea of Japan, protecting the Echigo Plain from flooding. The Okozu Diversion Project is a diversion channel, a wash weir, a movable weir, and a fixed weir.

Since the Edo era, residents of the neighborhood had petitioned against the construction of this diversion facility, but it was not permitted. At the beginning of the Meiji era, the national government began construction of the facility, but it was suspended in 1875. When an unprecedented flood occurred on July 22, 1896, following the break of the levee embankment called

"Yokota-giri," the national government decided to resume construction in 1907. The modern water diversion technology had been established through the Yodo River improvement work that had been carried out since 1895.

One of the features of the Okozu diversion is that the river width downstream was narrower than upstream. As the area near the river mouth is mountainous, the amount of excavation was reduced. However, from a hydraulic perspective, since the river width is narrowed, the river gradient is made steeper to increase the flow velocity for the required discharge.

Source: Shinano River Okozu Diversion Canal, one of the largest spillways in Japan, Kiyoshi Hirata Consultant Vol.238 Japan Construction Consultant Association
Photo: Shinano River Office, MLIT

However, in terms of water use, it was difficult to develop surface water for new water rights, and ground subsidence had begun to occur due to excessive pumping of groundwater as a source for urban water supply.

In addition to floodways and river shortcuts, such as the Okozu Diversion project mentioned above, river engineering technology was used to construct large dams in the upstream areas. As a forerunner, there was a boom in the construction of run-off type power plants in the Taisho era (1912–1926). Droughts were plentiful in the upper reaches of Japan's rivers, providing favorable conditions for run-off type hydroelectric power generation. In the Taisho era, the electricity demand grew rapidly owing to growing industrialization, and the hydroelectric power business grew rapidly. In 1924, the Oi Dam (53m high) was completed on the Kiso River system, marking the beginning of the era of large dams.

During the Showa era (1926–1989), the Komaki Dam on the Shogawa River (80 m high) was constructed in 1929, the Teishakugawa Dam on the Takahasi River (62 m high) in 1931, the Tsukahara Dam on the Mimi River (87 m high) in 1938, the Tateiwa Dam on the Ota River (67 m high) in 1939, and the Miura Dam on the Kiso River (83 m high) in 1943. Large dams were constructed successively, and the business of hydroelectric power generation and dam construction technology showed steady development.

(3) After the End of World War II

1) Revival Period (1945–1955)

Amid land devastation and economic turmoil, Japan, which has limited natural resources, had to rely on the effective use of domestic resources and land development. From the end of World War II until the Ise Bay Typhoon in 1959, Japan experienced a series of natural disasters that left more than 1,000 people dead or missing. The cost of damage was greater than 5% of the national income. The Makurazaki typhoon in September 1945, the Nankai earthquake in December 1946, the Kathleen typhoon in September 1947, the Fukui earthquake in June 1948, the Aion typhoon in September 1948, the floods in western Japan in June 1953, and Typhoon No. 13 in September 1953 left a huge mark across the country. Typhoon Aion in September floods in western Japan in June 1953, and Typhoon

No. 13 in September left large traces of damage throughout Japan. Due to inadequate disaster prevention and mitigation systems, damage to Japan's land and people was extensive.

In 1949, the Flood Protection Investigation Committee established by the Ministry of Home Affairs reported on the flood protection plan for ten rivers under the direct jurisdiction of the Ministry of Home Affairs because of the havoc wreaked by Typhoon Kathleen, and the flood protection approach was shifted to a multipurpose dam system including development of water resources. In 1950, with the promulgation of the Comprehensive National Land Development Act, the Land Conservation Project was intensively implemented as part of the Comprehensive River Development Project, which reduced the number of large-scale natural disasters and built the foundation for post-war reconstruction.

2) Period of Rapid Economic Growth (1955–1973)

The rapid development of social infrastructure since the post-war reconstruction period has eliminated bottlenecks and paved the way for economic growth. The development of hydroelectric power generation in the 1960s made a significant contribution toward energy production for industrial development. The Sakuma Dam, completed in 1956 with a total loan of $9 million from the Bank of America, was a pioneer in speeding up civil engineering work through the use of construction machinery, and changed the atmosphere of construction sites.

Environmental pollution problems began to appear in many parts of the country during this period. In 1953, people began to show symptoms of Minamata disease in the Kumamoto Prefecture, and itai-itai disease near the Jintsu River was reported at an academic conference in 1955. The Yokkaichi pollution emerged as a problem. Rapid industrial development has resulted in air and water pollution in many regions. Under these circumstances, the natural and social environmental impact of large-scale civil engineering projects have increased, and there is a strong need to understand disasters and pollution that are expected in the future from the development planning stage.

3) Stable Growth Period (1973–1991)

As large-scale projects were developed during a period of high economic growth, the natural and social environmental impact became more significant. Lawsuits demanding the suspension of projects, disasters (including floods), and cases blaming the government for the occurrence of accidents began to emerge. For example, in the wake of a disaster due to heavy seasonal rainfall in 1972, numerous flood lawsuits were filed all at once. Residents' awareness of public works and disasters changed from the late 1960s to the 1970s. In 1977, the Interim Report of the River Council indicated that comprehensive flood protection measures, such as watershed and damage mitigation methods must be strongly implemented along with river improvement. Since then, the government has promoted measures, such as securing water retention and recreational functions, setting up hazard maps of flooding, and public announcements. The government continued to seek understanding and cooperation from the watershed residents. Following the adoption of river improvement measures, construction of the metropolitan area outer discharge channel in the eastern part of Saitama Prefecture began in 1992 and was completed in 2006 as one of the world's largest underground waterways. This contributed toward the safety of Tokyo's capital city.

Japan became one of the world's largest economies in the 1980s due to high economic growth; however, the standard of living and welfare was still low, with small living quarters, difficult commuting conditions, and low penetration of sewage systems. The country could overcome the problem of severe pollution to a large extent and income levels increased, people regained comfort with the hope of improving their living environment. Until Japan attained a period of high economic growth, people were striving for uninterrupted economic growth and were living in circumstances that included polluted rivers, lakes, marshes, and unsettled cities and roads. In 1970, the "National Diet on Pollution" was convened with the aim of drastically improving pollution-related laws and regulations, indicating the need to improve people's living environment. Civil engineering shifted from functional supremacy and priority to economic benefits, aiming for its original form of prioritizing the improvement of the living environment through the creation of amenities for beautification.

Against this social background, since the mid-1970s, attempts were made to introduce amenities for leisure as well as achieving peace of mind into civil engineering projects, including rivers, roads, and urban planning, primarily to harmonize them with improving the original functions. It was a new attempt that aimed at designing civil engineering spaces for recreation and leisure for people to enjoy considering the landscape together with adopting measures to prevent environmental pollution, and projects to solve these problems became widely popular in the 1980s. While environmental restoration, rehabilitation, and creation of waterfront spaces, landscape designing, beautiful and comfortable roads, and development of waterfronts, as seen in the creation of coasts and harbors, have progressed, non-structural public works projects have been introduced, such as attractive water and bridges that can be used for tourism. The development of sewage treatment technologies, such as advanced treatment and resource reuse, has played a significant role in expanding sewage projects. At present, although some scholars point out the loss of regional individuality due to uniform development and urbanization, public works projects have shifted from focusing solely on economic rationality to project implementation, considering the improvement in environment and quality of life.

4) Post-growth period (1991- present)

In the era of high economic growth and the spillover effects to rural areas, civil engineering technology has promoted national land development and fulfilled social requirements in the form of building large infrastructure projects, such as dams, highways, Shinkansen, and ports.

Civil engineering technology has reached a turning point and has faced severe trials. Criticism of public works projects triggered by the campaign against the Nagara River estuary barrage transcended the issue of "development" or "environment" and has turned into a social problem. It became the forerunner of the criticism of the public works projects that followed. Criticism of public works projects has provided an opportunity to question how governance should be conducted, such as technical issues, social issues, criticism of the high-cost structure, and innate characteristics of the construction industry, and decision-making on public work projects. Prior to the above, in the long-term plan for social capital development to promote development in a focused, effective, and efficient manner, the plans for each business field were unified, and the plans were changed from "project cost" to "achievement results." The "Social Capital Development Priority Plan Act" was enacted in 2003, and the "Social Capital Development Priority Plan" based on the Act was determined by the Cabinet during the same year.

The Basic Environment Act was enacted in 1993 to comprehensively develop new environmental policies for the global environmental era.

Until the period of high economic growth, civil engineering created the foundation to support economic growth that emphasized growth in the gross national product (GNP). Currently, a shift to global environmental issues, social safety, stock-oriented in-house production of distinct regional diversity, and building a foundation aimed at becoming a mature economy that citizens can be proud of is underway.