FLOOD CONTROL WORKS IN JAPAN
~ ACHIEVEMENTS TO DATE AND FUTURE OUTLOOK

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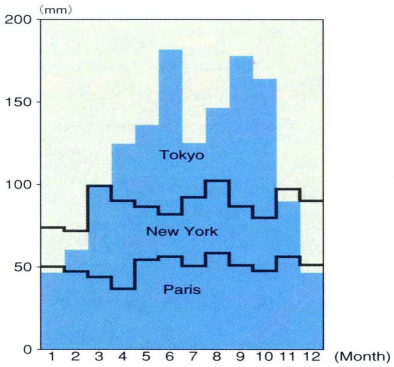
1 History of flood control projects

1.1 Natural and social conditions in Japan

(1) Natural conditions

The islands of Japan are located between 20° 25' and 45° 30' north latitudes, or in temperate Monsoon Asia. Seventy percent of the land is covered with steep mountains, many of which are volcanic. The geology consists of weak soils.



Notes: Source:Rivers in Japan(MLIT)

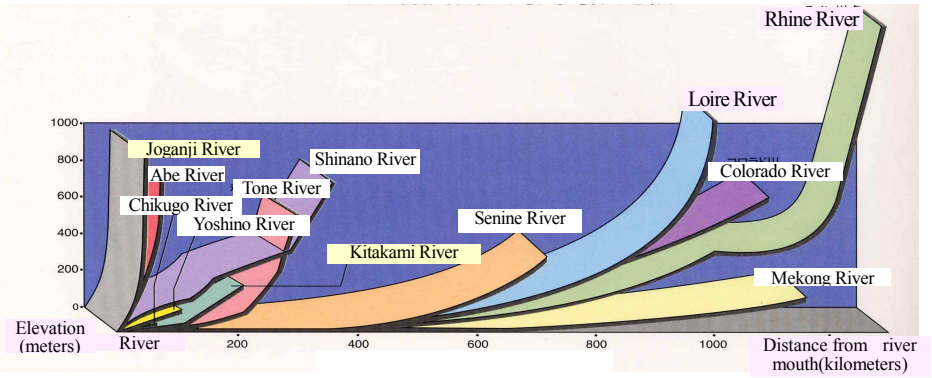
Figure. 1 Monthly precipitation in Tokyo, Paris and New York

Temperature is affected by the southeastern wind from the Pacific in the summer and by the northwestern wind from the Eurasian continent in the winter owing to the location of the islands. Areas along the Sea of Japan are covered with world-class heavy snow in the winter. Both seasonal rain and typhoons hit the nation in the summer, often inducing downpours. In areas along the Pacific coast in particular, 50 to 60% of annual precipitation is concentrated during the summer.

Rivers that catch water in their basin while flowing are greatly affected by the topography and climate described above, and exhibit the following characteristics as compared with large rivers on the European continent and in other places.

(a) Japanese rivers are steep-sloped

Many of the Japanese rivers are steep-sloped and flow down mountains quickly to the sea from their headwaters over short distances.

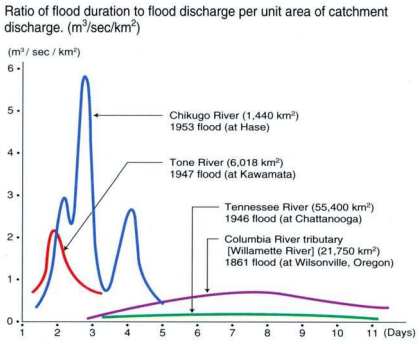


Notes: Source:Rivers in Japan(MLIT)

Figure. 2 Longitudinal slopes of rivers in Japan and other countries

(b) Water level rises quickly in Japanese rivers

Japanese rivers have much smaller catchment areas than major European rivers. Even Japan's largest catchment area of 16,840 km2 of the Tone River is only one-fifth of that of the Seine. Heavy rains frequently fall locally in Japan. Water level rises in rivers with a small catchment area as soon as the entire catchment area receives heavy rains. Actually, once rain falls, the water level rises at a rate of dozens of centimeters per hour.



Notes: Source:Rivers in Japan(MLIT)

Figure. 3 Characteristics of flood runoff in Japan

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(c) Great variation in volume of river water throughout the year

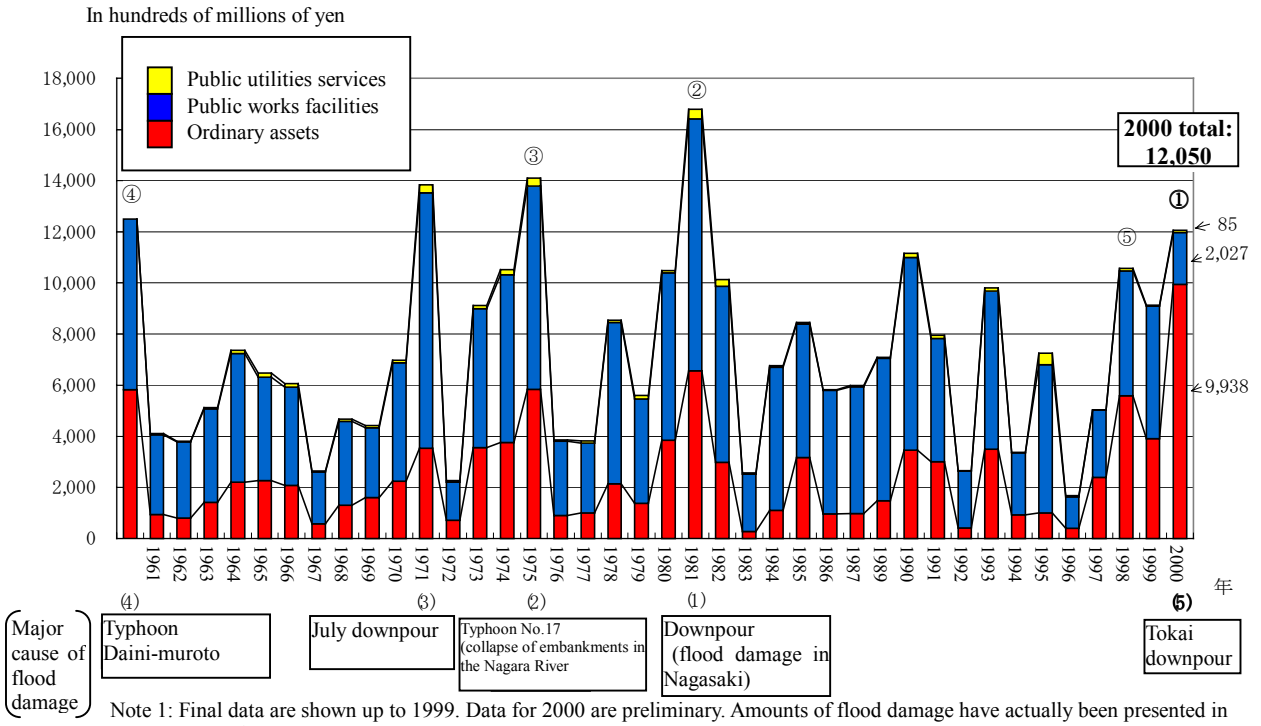
Japan's steep-sloped rivers with a small catchment area experience quick rise in water level during heavy rains and soon go dry during lasting droughts.

(d) Great effect of sediment transport

Japanese rivers flow swiftly and soils are loose, so more sediment is transported into rivers than in Europe. Alluvial plains where many people have settled were originally formed by the sediment transported by rivers. Containing rivers with embankments soon caused sediment to be deposited and thus made rivers even shallower, which in turn created flood-prone conditions.

(2) Social conditions

Owing to the natural conditions described above, 50% of nation's population and 75% of national assets are concentrated on alluvial plains that account for only 10% of land. Flooding therefore could cause devastating damage.



Note 1: Final data are shown up to 1999. Data for 2000 are preliminary. Amounts of flood damage have actually been presented in 2000 price.

Note 2: No investigations were made of the damage to public utilities services in 1961.

Note 3: Figures in the parentheses indicate the ranks in total flood damage amount (top five in the descending order). Encircled figures indicate the ranks in the amount of flood damage to ordinary assets (top five in the descending order).

Note 4: Average in the period between 1961 and 1999: 714.3 billion yen (ordinary assets: 23.1 billion yen, pubic works facilities: 47.2 billion yen, public utilities services: 11.3 billion yen)

Figure. 4 Changes in density of flood damage to ordinary assets, etc. (average in the past five years)

Damage has actually been caused every year by rainfalls during the rainy season and typhoon-induced downpours. Last year in particular, serious damage was sustained in the Tokai district, the central part of Japan, centering around Nagoya. The high percentage of general damage to homes and offices was noticeable. Flood control projects have long reduced the area of inundation. Concentration of assets in floodplains, however, has increased their value per unit area. Thus the amount of damage has hardly decreased.

1.2 History of flood control projects

Recent flood damage has been described above. Japan's flood control projects have been carried out assiduously to tame natural conditions.

(a) Flood control by local protection (before the Meiji Era (1868-1912))

Japan's oldest recorded flood control project is said to date back almost to the third century when the Manda Embankment was built in the Yodo River.

In those days, flood control mainly aimed at protecting local areas from disasters. In order to protect local agricultural fields and communities from flood damage, measures were taken according to the importance of the locality or topographic and other natural condition. Embankments were designed to have varying heights on both banks of rivers or in upper and lower reaches. Embankments were installed near the community not along the river to prevent the inflow of flood waters. And forests for controlling flood disasters were created in the places where flood waters were to be let overflow to mitigate the energy of flood waters. In areas constantly hit by floods, land was elevated and shelters were installed on highland, and boats were prepared for evacuation. Thus local residents took anti-flood measures by themselves.

With the concentration of authority, flood control gradually became one of the key national projects for political leaders not only to stabilize people's life but also to develop new agricultural fields in flood-prone lowland for the growth of national strength. It was widely believed that "Those who rule rivers rule the nation." In the age of civil wars, large flood control projects were implemented in some areas.

(b) Navigation on rivers and low-flow channel improvement

(in early days through middle of the Meiji Era)

Following the Meiji Restoration (1868), the development of new industries was encourage to establish a modern state. Inland transport of large volumes of goods at the time depended mainly on navigation, so rivers served as the main economic artery. River improvement was the nucleus of the national economic policy. Low-flow channel improvement work was carried out by the national government in the Yodo River in 1880. Flood protection work, on the other hand, was performed mainly by local administrative agencies focusing on local benefits.

Flood damage was sustained frequently in late 1870s through early 1890s in large rivers such as the Yodo, Tone and Kiso Rivers. Thus the need for drastic flood control measures was realized. In the meantime, the development of railway networks reduced the role of navigation, and rapidly made low-flow channel improvement works to facilitate navigation less important.

(c) Approach to flood control led by the national government

(late in the Meiji Era through mid 1940s)

The River Law was established in 1896 and the Sediment Control Law and the Forest Law were enacted in 1897, laying the foundations for modern flood control. The River Law provided basic principles for river administration in Japan until its revision in 1964.

The River Law defined rivers as facilities built by the national government and stipulated that they should be managed by local administrative agencies as national organizations. Private rights were eliminated to the use of rivers, river terraces and flowing water as long as they have an important bearing on public interest. The Law held local administrative agencies primarily responsible for river works and maintenance of rivers as in the past. However, for the works that were expected to affect other prefectures, require high-level techniques because of difficult nature, cost more than a local government can bear or be important improvement projects based on a total plan, the national government was made to assume the responsibility for implementation.

Nationwide great flood damage in 1910 triggered a study of the first-phase flood control program. The rivers requiring national projects for improvement were selected, and construction priorities, periods and costs were discussed. Accordingly, the government appropriated necessary fund and started flood control works.

(d) Development of infrastructure for economic growth

(in mid 1940s through mid 1960s)

Flood control projects made only a limited progress during World War II. Typhoon Catherine and a succession of other large typhoons frequently hit the land devastated by the war in mid 1950s through late 1950s causing great damage. In the wake of Typhoon Ise Bay of 1959, the Erosion and Flood Control Emergency Measures Law and the Flood Control Special Account Law were instituted in 1960, and Japan's first long-term (ten-year or five-year) flood control programs were developed based on the laws.

In the meantime, in order to meet the rapidly growing demand for industrial and municipal water owing to economic development, water resources were developed by building multi-purpose dams for flood control and water use, and the construction and management of dams were centrally controlled by river administrators.

As a result of economic and social development and the modification of administrative systems since mid 1950s, the River Law was completely revised in 1964. This is because needs arose to review distributed river management by prefectural governors by administrative district as a result of a considerable reform of nation's administrative system with the establishment of the existing constitution, because the needs increased to revise the conventional section-based river management system and to introduce integrated management of entire river systems in order to respond to the development of riparian zones and the increase in demand for various types of water use with the social and economic development, because the needs increased to improve water use related regulations for coordinating new water use with existing water use with the progress of water use projects, and because the needs arose to enact regulations for controlling damage caused by dam operation with the building of numerous large dams using advanced construction techniques.

Then, establishing "basic plans for implementing construction works" was made mandatory in river administration. Thus a great shift was made from management of river sections to integrated management of river systems covering lower through upper reaches.

(e) River improvement corresponding to rapid urbanization

(in mid 1960s to present)

With the advent of the high economic growth period around the time when the new River Law was instituted, cities and industries grew rapidly. At the same time, accelerated urbanization induced various problems in relation to rivers such as water pollution in rivers and lakes, frequent urban flood damage due to delays in flood control measures, serious water shortages including the drought in 1964 when the Olympic Games were held in Japan and rapid increases of sediment disasters.

Measures have been taken sequentially to control the pollution of river water, to comprehensively control floods by establishing warning and evacuation systems as well as detaining rainwater, and controlling infiltration and sediment disasters while improving rivers, and to control droughts by building dams. In order to avoid catastrophic damage in urban areas where assets are concentrated and critical jobs are performed, by the failure of embankments due to floods that exceed the design level, the idea of high-standard embankment has been introduced.

At present, various projects including the development of flow conservation channels and nature-oriented river works are being implemented for better river environments not only to control and use water but also to improve water quality, preserve resting and breeding areas for wildlife species and offer people easier access to waterfront.

In 1997, the River Law was revised to incorporate the conservation and improvement of river environments as one of the objectives of the law.

The next chapter describes the role that flood control projects have played using typical examples in the metropolitan area.

2 Flood control projects in metropolitan area

2.1 Eastward relocation of Tone River

(metropolitan flood control project started at the end of the 16th century)

2.1.1 Outline of eastward relocation project

The Tone River in the pre-modern days belonged to a river system different from the one that incorporated the Kinu and Kokai Rivers, and flew over the Saitama Plains in several threads toward Tokyo Bay. After Tokugawa Ieyasu, a warlord, moved to Edo (ancient name of Tokyo) in 1590, Ina, the local governor, led rerouting of the Tone River in several phases during the first 60 years in the Edo Era (1603-1867). As a result, the present alignment of the Tone River was formed that flows into the Pacific.

The project to move the Tone River eastward took place during the 60-year improvement works between the coffering of the Kaino River in 1594 and the discharge of water in the Akahori River in 1654.

Conceivable goals of the eastward relocation of the Tone River include "protection of Edo from floods", "development of new agricultural fields", "securing of navigable channels", "military defense against the Date clan" and "improvement of roads". Without the river improvement project, Edo would not have existed. The eastward move of the Tone River that was started 400 years ago laid the foundations for later large-scale urban development leading to a flourishing Tokyo.

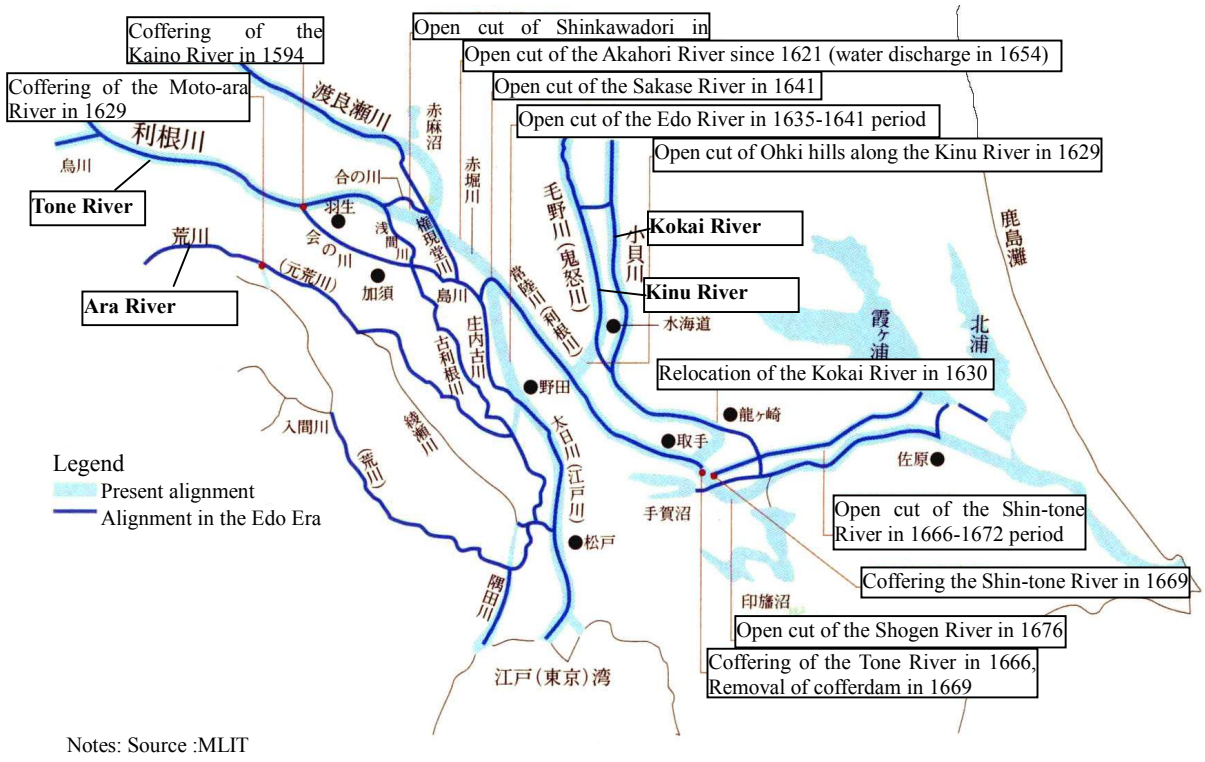


Figure. 5 Eastward relocation of Tone River

2.1.2 Effects of eastward relocation on the development of new agricultural fields

Moving the Tone River to the east integrated the Tone and Ara and other rivers that use to be turbulent channels on lowland in the east of Saitama prefecture, and enhanced drainage in the swamp, creating a great farm belt in the basin of the Tone River.

The development of new fields increased not only the yields but also the population and villages. The yields from paddies in the Musashi province consisting of Katsushika, Saitama and Adachi gun (counties) that were affected most by the relocation of the Tone River grew about 200% in the 100-year period since 1550. The number of villages increased accordingly.

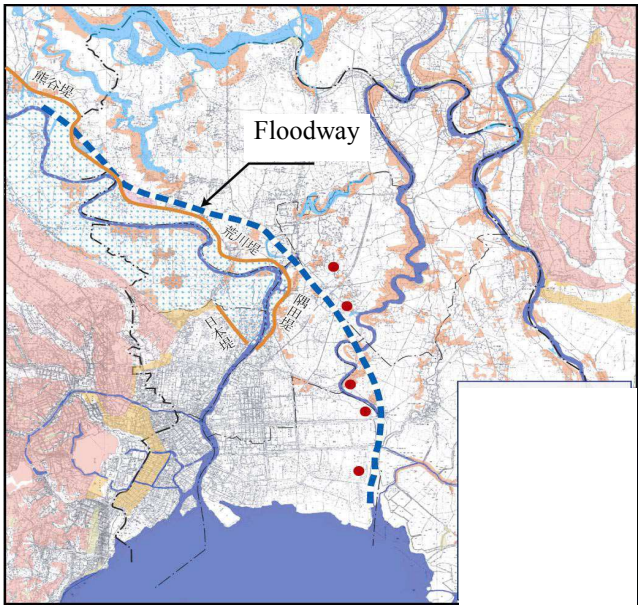
2.2 Construction of the floodway of the Ara River

(modern flood control project started at the end of the 19th century)

2.2.1 Outline of the floodway construction project

Flood damage that had been sustained approximately once in three years since the Meiji Restoration became more serious with the urbanization of Tokyo. The national government in the Meiji Era built groups of cement, shipbuilding and fertilizer plants near the mouth of the Sumida River as national priorities. After the Sino- and Russo-Japanese wars, the industrial area in the east of Tokyo endowed with navigation channels expanded. In early 1900s, plants were also constructed in the middle reaches that were in use for a water retarding area, owing to the construction of the Nihon and Sumida embankments.

As a result of the great flood in 1910 and in view of the need to build the port of Tokyo, construction of a floodway of the Ara River was started as a critical measure to protect the downtown area of Tokyo from flood damage. The large scale project to excavate the floodway 22 km long and 500 m wide was completed in 1930, 20 years after the commencement of work. At the completion of the project, Tokyo's economic strength exceeded that of Osaka, then the center of the Japanese economy, which has led to the present growth.



Notes: Source: MLIT

Figure .6 Construction of floodway of the Ara River

2.2.2 Effects of flood control project in urban areas (lower Ara River and Tokyo metropolitan area)

(1) Changes in land use

Changes in land use for the past 100 years along the floodway in the Tokyo metropolitan area are discussed below. Urbanization along the floodway progressed in two major districts that were formed before and after the completion of the floodway.

(a) Area urbanized before the completion of the floodway

(on the right bank of the floodway)

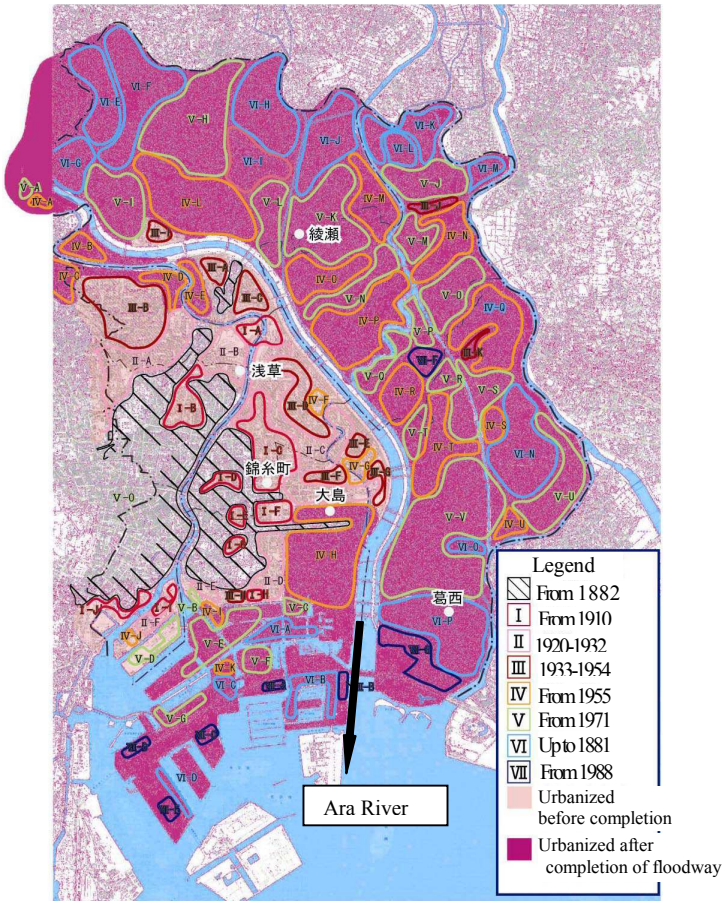
Urbanization progressed centering around the old city center of the Edo Era and along the railways laid in the Meiji Era. As a result, urbanization was completed on the right bank of the floodway before the completion of the floodway except some parts along the floodway.

(b) Area where urbanization progressed after the completion of the floodway

(Adachi, Katsushika and Edogawa wards on the left bank of the floodway)

Urbanization progressed to the left bank of the floodway after the completion of the floodway in 1930 centering on railway stations and in districts subjected to land rearrangement. Urbanization started at bridges and trunk roads over the floodway or around railway stations, progressed to surrounding areas and was nearly completed in the 1980s.

In 1910, the development of the urban area in the east of Tokyo was at a standstill, restrained by flood-prone swamps. The lowland that used to be vulnerable to flooding of the Ara and Edo Rivers turned to the present condition with more than 1.6 million population and concentrated assets, owing to the completion of the floodway in 1930, after experiencing the damage by World War II and post-war economic growth.



Notes: Source :MLIT

Figure. 7 Phases of urbanization

(2) Effects of flood control project

(a)

The flood control project by constructing the floodway of the Ara River not only mitigated flood damage to the riparian zones but also satisfied the key requirements for regional development by increasing the safety of land from floods. Thus, the project created ripple effects on the development of building land, and improvement of transportation and other urban infrastructure systems, resulting in the revitalization of economic activities in the city. In Japan, the effects of flood control projects are now evaluated not solely in terms of disaster control but the need to evaluate projects as the "infrastructure of infrastructures" based on long-term judgement of overall regional social and economic performance is being realized again.

The project for constructing the floodway of the Ara River produced the following ripple effects on various socioeconomic activities in the following steps over the past 90 years.

1) The flood control project increased the effectiveness of disaster averting measures, and regional safety.
2) Increased regional (land) safety promoted the development of building land.
3) Increased regional (land) safety accelerated the improvement of other (transportation, living and industrial) infrastructure systems.
4) Land development and improvement of infrastructure encouraged the concentration of population and the starting of business.
5) Economic activities expanded.

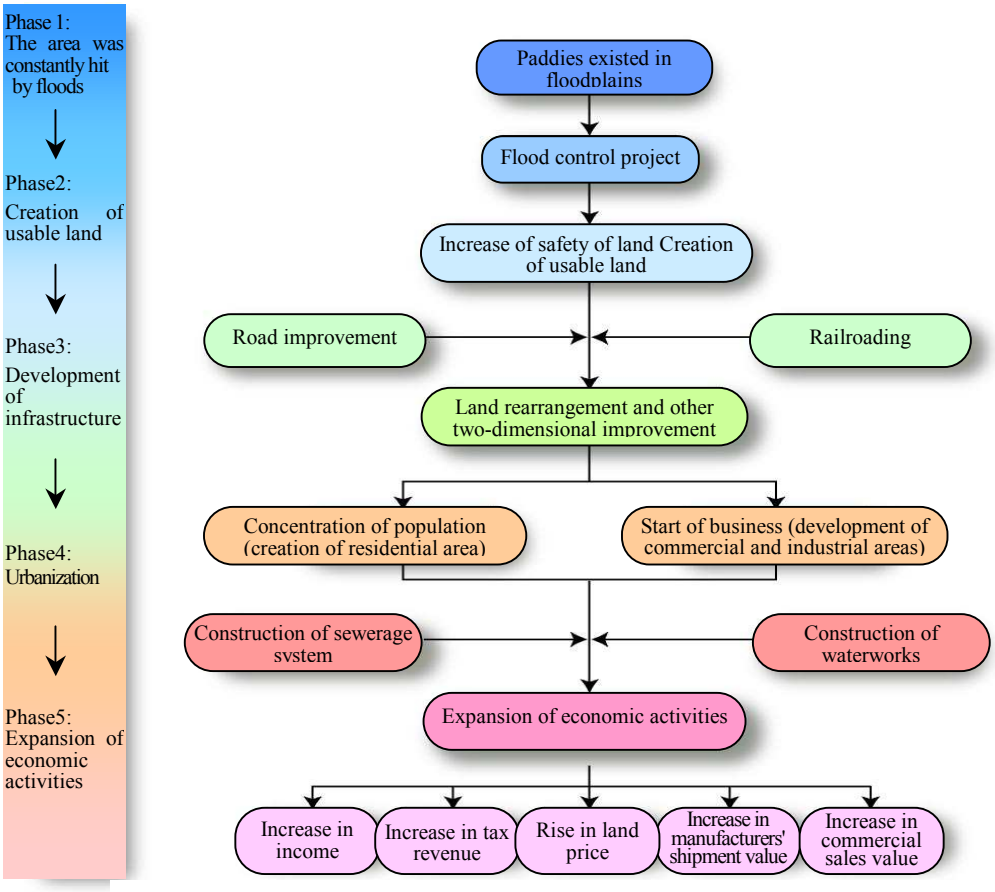


Figure. 8 How the effects of flood control project spread

(b) Investment in infrastructure and economic activities

1) Effects of concentration of population
In Edogawa, Katsushika and Adachi wards, residential space has been provided to 1.63 million people, about five times larger than 310,000 90 years ago, during the 90-year period since the commencement of construction of the floodway.

2) Effects of encouragement of investment in infrastructure
Housing investment increased right after the completion of the floodway in 1930. Cost of urban development rapidly increased in the 1955-1970 period. Flood control project cost also increased five years later mainly for areas behind the embankments. The flood control projects mainly consisted of control of high tides due to settlement and construction of drainage facilities.

3) Effects on economic activities
Manufacture's shipment value started increasing in the three wards around 1950. Then, commercial sales value also increased from around 1960. This means that the area initially developed as an

industrial area and then turned into a residential area incorporating a commercial district. Economic zones have been created in the three wards that now yield a combined total of commercial sales and industrial shipment at 5 trillion 400 billion yen per year.

3 Jobs to be done on flood control projects

Flood control projects, while supporting the social and economic development of Japan, induced the concentration of large population and assets on floodplains. The population and assets in potential flood areas increased about fourfold and 140-fold, respectively in 100 years since 1875.

Failure of embankments in the metropolitan area is therefore expected to have an extremely serious impact not only in the damaged area but also on Japan's social and economic activities.

In recent years in particular, urban flood damage has been caused in which big cities such as Tokyo, Nagoya and Fukuoka were hit by heavy rains and urban functions were paralyzed. Urban flood damage includes not only general damage to homes and offices but also the paralysis of transport and information exchange systems. Inundation of underground shopping centers even claimed some lives.

Under the circumstances, emphasis has been placed on the following major jobs.

3.1 Total flood control measures throughout the basin

Flood control measures have been focusing on river improvement. Today, in addition to proceeding with river improvement, total flood control measures are being applied by increasing the water detention and retardation capacity of basins, installing facilities to control storm runoff, and using land and building houses so as to minimize inundation damage.

Figure. 9 Multi-purpose water retarding area for the Tsurumi River

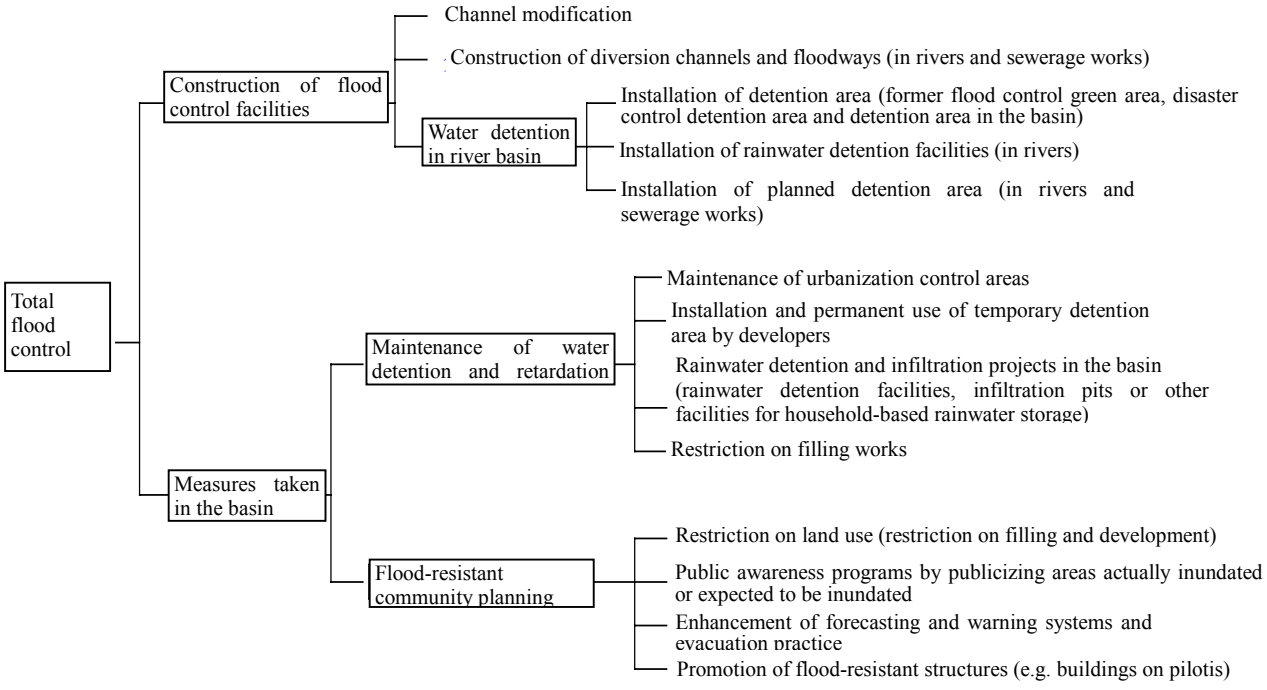


Figure.10 System for total flood control

3.2 Preparedness for floods exceeding design level and restoration of urban riparian zones

Many of Japan's cities are located on alluvial plains. Some are at sea level and protected by embankments as high as 10 m. In these areas, especially in the Tokyo metropolitan area or Kinki (western Japan) area, failure of embankments could cause devastating damage. Super (high standard) embankments therefore have been constructed to prevent the failure of embankments by overflowing floods exceeding the design level from causing catastrophic damage. Construction of such embankments requires coordination with community planning. Comfortable communities equipped with building land and parks are planned with the construction of super embankments with moderate slopes. At present, eliminating districts where wooden houses are densely located is essential not only to fire fighting but also for restoring and revitalizing urban areas. Creating safe and comfortable riparian zones in cities by constructing super embankments would greatly help achieve the objective.

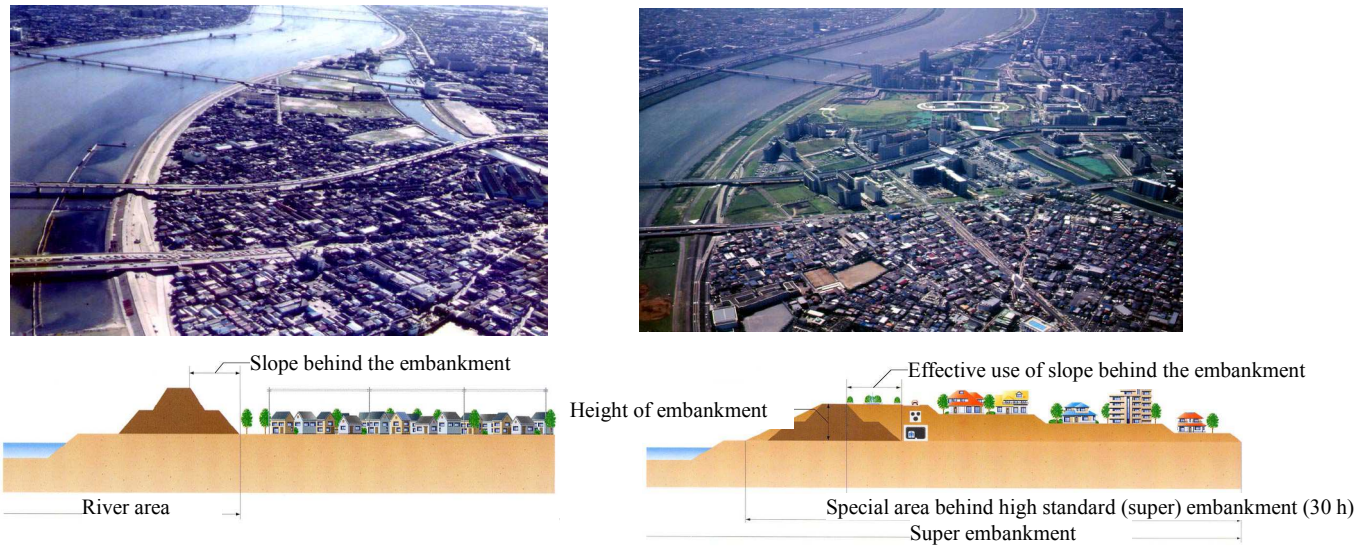


Figure. 11 Construction of super embankment

3.3 Promotion of development of flood control software

The Tokai disaster in 2000 made the threat clearly understood that people became less aware of the danger of flood disaster as a result of developments in river improvement and sewerage system development, and urbanization.Hardware solutions have been applied. In view of recent flood damage due to heavy rains, risk management for mitigating disasters is also being demanded.

For the rivers for which flood forecasts were made mandatory, dissemination of information by flood forecasts or other means has been promoted. At the same time, flood hazard maps have been prepared to encourage residents to take shelter by themselves in emergencies. In the wake of last year's Tokai heavy rain, the Flood Fighting Law was revised to enhance flood fighting efforts. Hazard maps should be prepared in coordination with municipalities so as to encourage residents to take appropriate action in emergencies.

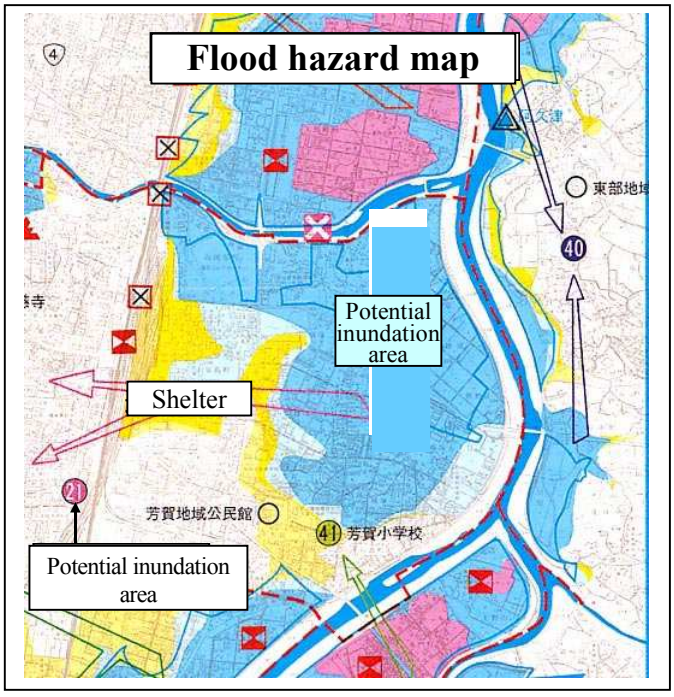


Figure. 12 A hazard map