DEVELOPMENT OF WATERWORKS IN JAPAN

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INTRODUCTION

JAPAN has a long tradition of public water service which dates back to the Edo waterworks. During the rapid process of her modernization in social structure and institutions, in technology and way of life which followed the Meiji Restoration, both the citizens and government authorities were enthusiastically interested from the outset in building modern waterworks. The importation of modern waterworks technology from the West and its assimilation, together with the promotion and development of modern industry and local production of required materials, which would help accelerate the extensive proliferation of such urban facilities, seem to have achieved generally smooth progress. However, the spread of water service networks, which are usually considered one of the most basic and indispensable facilities for modern urban life, was disproportionately slow. For decades, it was a common phenomenon for urban life to be deprived of the benefit of a public water supply, not only in the rural areas but also in the satellite cities of Tokyo. In spite of the early enthusiasm of the government, construction of modern waterworks often ranked low on the priority list of social capital build-up and public engineering works in Japan. Over the years that followed, it was seldom, if at all, given a dominant position. Further, in sharp contrast to the significantly rising concern of citizens over the sanitary aspect of waterworks during the early years of the nation's modernization, urban dwellers' recognition of waterworks as an indispensable facility for sanitary urban life was rather slow to take root and spread. As a consequence, cities sprawled into their underdeveloped outskirts, and the inadequacy of water service facilities did not necessarily constitute a substantial impediment to urban development.

Underlying the early public enthusiasm for the construction of modern waterworks was the general feeling of unrest over sanitary problems aroused by the infiltration from overseas and extensive prevalence of such waterborne epidemics as cholera and dysentery and, ensuing from this, the increasing recognition of the urgent necessity of waterworks construction as the only effective step to prevent those maladies. In cities where human activities are carried on in a high density, once a waterborne epidemic arises, there is a great danger that

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its germs may be proliferated via water to contaminate the drainage texture and thereby cause extensive prevalence in a short period of time. When bacteriology was still in its primitive stage, the only available way to prevent any epidemic from spreading further was through sanitary engineering measures involving the use of water supply and sewerage systems—clearing water of bacteria in a filter basin, distributing purified water through sealed pipes to protect it from contamination in the city and discharging contaminated sewage out of the city through its sewerage system. In ancient and medieval times, West European cities were often attacked by waterborne epidemics, sometimes so heavily that the whole population of the city affected was exterminated, and for many centuries since the middle ages they have successively improved their water supply and sewerage systems to keep their environment sanitary and thereby to hold epidemics in check. The modern waterworks and sewerage technology introduced to Japan had developed from this historical background. However, by the end of the nineteenth century when modern waterworks began to be built in Japan, bacteriology had achieved rapid progress especially in Germany, and most up-to-date medical knowledge in this area was quickly conveyed to Japan as well, making it possible to suppress epidemics at their very origin. This progress in techniques of public health and hygiene helped localize any anxiety that might have arisen over suspected contamination of otherwise potable water with pathogenic bacteria, and prevented it from taking on national dimensions. As a result, urban dwellers came increasingly to see waterworks less as a public sanitary facility than as a mere utility allowing them to readily obtain water by simply turning a cock. The setback in public consciousness of this aspect of public sanitation even more seriously affected the spread of sewerage systems than that of waterworks. The people recognized the benefit of sewerage less than that of waterworks because their lack of a correct understanding of water pollution. It was not until the 1960s when the Japanese economy began to achieve rapid growth that there reemerged nationwide concern over the frequent pollution of river systems from the viewpoint of environmental hygiene, the pollution this time with heavy metal compounds discharged from industrial plants.

The early enthusiasm of citizens for construction of modern waterworks was endogenously motivated by their everyday needs, above all their concern about public hygiene, but government authorities looked upon urban modernization partly as a matter of giving the nation a decent appearance which, they expected, would help strengthen their position in demanding the amendment of unequal treaties, and this incidental motive eventually turned out one of the factors that contributed to reducing the relative importance of waterworks in the overall program of public works as Japan's modernization achieved some progress. Even in the Tokyo City Replanning Commission, which was energetically working on its waterworks construction program, its chairman Akimasa Yoshikawa who concurrently was vice-minister of the interior said, already before the start of actual construction, "Roads, bridges, and rivers are the root; waterworks, housing, and sewerage are branches." Here we find an early sign of the subsequently predominant mentality of giving priority to industrial infrastructures at the sacrifice of facilities for citizens' everyday life. Like waterworks and sewerage projects which the Waterworks Ordinance prescribed to be undertaken by municipalities, many of the local governments' tasks directly affect citizens' daily life. However, in the process of Japan's modernization which, under the slogan of "Increase production and develop industry; enrich the nation and strengthen the military," was oriented toward imperialism with increasing explicitness, the priority of industry over individual citizens and of the central government over municipalities was steadily established. Under this circumstance, waterworks projects were gradually alienated from the main stream of public works.

Meanwhile, the development of big cities in the lower reaches of major rivers and the growth of industry in the cities increased the importance of protecting urban areas from floods, and at the same time the expansion and improvement of railway service decreased the need for river boats as means of inland transport. In the history of river engineering in Japan, traditional technology since the Edo period predominantly emphasized low water work intended for flow stabilization to facilitate boat traffic and irrigation, and modern technology imported after the Meiji Restoration again primarily comprised of low water know-how of Dutch origin. Owing to such changed circumstances as well as to the enactment of the River Act in 1896, the major method of river engineering came to be based upon high water projects the objective of which was to isolate rivers from towns and cities with the construction of consecutive embankments and to enhance the speed of floodwater flow into the sea. This change in technological conception of the relationship between rivers and cities and the priority given to flood control over water utilization also served indirectly to reduce the relative weight of waterworks projects in river engineering at large.

What influenced the development of waterworks even more than these circumstances was the unique way in which Japanese cities had been linked to farm villages and natural ecosystems and which characterized the developing pattern of cities in this country. In Japan, traditionally, cities had not been so much perceived as artificial environment in which nature is controlled with man-made facilities, but usually developed in a pattern in which they expanded, dependent on rich natural environment surrounding them, inseparable from rural districts. From the standpoint of city planning, urban and rural areas were continuous. On the part of farmers, they long continued to use human waste as fertilizer, resulting in a close link between cities and farm villages in this aspect, too. Thus was traditionally established an ingenious order of ecocycles in which cities and villages were integrated. The function of sewerage consists in isolating urban filth from the natural environment, disposing of it and returning only treated water into the river system by carrying and concentrating filthy discharge from city life and properly treating it. Underlying this is the idea of separating human activities and their physical consequences from nature, which is essentially different from the rural way of life in which human activities are regarded as part of natural ecosystems and filthy discharges therefrom are dispersed and contained in the natural environment and treated by its own purifying action. As Japanese cities expanded preserving much of this rural way of life, need for sewerage was not so urgent until a certain stage of their development, and accordingly their inhabitants remained little aware of its necessity. As regards waterworks on the other hand, since a large proportion of urban Japan was blessed with ground water of potable quality, dependence on household wells did not prove so critically inconvenient. In principle, waterworks and sewerage together constitute an integrated system. In this country the inadequacy of sewerage retarded the proliferation of flush toilets and, because of this way of life it reduced the necessity of waterworks.

Where a city sprawls ahead of the construction of urban facilities, the sprawly area is likely to be more of a slum than the better equipped central district, but this was not the case with Tokyo. For instance the western suburb (including Musashino City), where waterworks were built only recently, was considered a decent residential district from the very outset of its urbanization, and it is now counted among the best dwelling quarters in Greater Tokyo. Whereas the urbanization of this area made quick progress in the 1920s after the Kantō Earthquake, the new population which inhabited the area consisted mainly of white collar workers. This group which became an important managerial element in Tokyo, began to expand rapidly at that time, and typically represented the subsequent urban way of life. This circumstance seems to indicate that the presence or absence of waterworks led to little, if any, social difference in a way of life and other aspects. Viewed the other way around, the presence of waterworks had created no particular "urban" way of life by that time.

This and other new suburban areas, as they were increasingly urbanized, suffered contamination of ground water by their own sewage and therefore came to need the construction of waterworks.

Thus, until a certain stage of urbanization, waterworks was not considered a basic requirement of a city or an indispensable prerequisite to urbanization. In not a few instances, development of urban districts preceded the construction of waterworks to serve the districts. In this sense, waterworks do not seem to have constituted a substantial limiting factor to the development of cities in the Japanese process of modernization and urbanization and, unlike railways, to have determined the direction of expansion or the form of the urban area.

It was stated that Japanese cities retained a rural pattern of links with river systems with the result that, before their dimension, population density, and activities went beyond certain limits, they had been well incorporated into and maintained a balance with the order of natural cycles. However, the expansion of cities proceeds under a different principle from that of natural balance and, because urban areas were developed at the beginning without the usually required physical facilities, there eventually arose various problems, above all that of the pollution of river systems.

During the phase of rapid economic growth after World War II, the increasing electrification of household chores and the progress of motorization transformed Japanese cities into highly water-consuming societies, and moreover the proliferation of flush toilets and of multi-storied buildings have made urban life vitally dependent on waterworks. Along with this process, the construction of waterworks has achieved rapid progress, and the proportion of the population thereby served has reached a remarkably high level. Yet, the spread of sewerage system, which theoretically should be inseparable from waterworks, still lags very much behind, and large quantities of household sewage are discharged untreated, with the consequence that urban dwellers are compelled to use more expensive water of inferior quality owing to the deterioration of raw water for waterworks and the increased distance of its intakes.

Blessed with supply of good water, Japanese cities previously consumed water with comparatively little worry. Quantitatively as well, although there were many difficulties in adjustment with vested water rights to use the surface water of rivers, they were able to meet an enlarged demand by tapping increasingly distant sources and developing seasonal surpluses therein. In the Kantō, Kinki, and northern Kyūshū regions, however, a very high proportion of the total water resources is already utilized and few suitable sites remain for dam construction, so that development of new water resources is nearing its limit (see Appendix Table I). This problem will soon be joined by that of existing reservoirs being filled up with mud and sand. Whereas waterworks serve not only households but also, to a substantial extent, offices and industrial plants, many of the latter used to satisfy their water needs inexpensively with ground water drawn from their own wells. However, as a result of massive mining of ground water brought on by postwar economic growth, subsidence has occurred in big cities, and to cope with this problem the Industrial Water Act was enacted in 1956, followed by the Industrial Water Utilities Act in 1958. As a result, the dependence of a water supply on rivers further increased, resulting in even greater needs for integrated development of new water resources, but in some of the more advanced regions new resources scarcely remain to be developed. Unlike demand for water which increases with economic growth and a rise in the standard of living, the total quantity of maximum available water resources is absolutely limited by the natural conditions of the nation's land. This limited nature of water sources is made increasingly evident by the consequences of postwar economic growth in Japan. When the national economy was still rapidly growing, the problem of water did not seem to have so decisively constrained the expansion of cities, but the situation has completely changed now. In the Third Comprehensive National Development Plan formulated in 1977, water resources are considered one of the most stringent constraints to regional growth, and in this connection the program spelled out an idea of development calling for the allocation of population and industry matching the maximum available water resources in each river basin, which is used as a basic planning unit.

I. DISTINCTIVE FEATURES OF WATER RESOURCES IN JAPAN

Technology of water utilization, including that of water supply, is naturally influenced by the way in which water resources exist. It seems relevant here to describe briefly the distinctive features of water resources in Japan as they relate to the functions of waterworks. The basic functions of waterworks technology can be

TABLE I

WATER ANALYSIS OF JAPANESE AND FOREIGN RIVERS

(ppm)

	Ca	Mg	Na	K	CO_3	SO_4	Cl	NO_3	SiO_2	Fe_2O_3	Evaporation Residue
Average of world rivers	20.4	3.4	5.8	2.1	35.2	12.1	5.7	0.9	11.7	2.8	99.9
Average of 225 Japanese rivers	8.8	1.9	6.7	1.2	15.2	10.6	5.8	1.0	18.7	0.3	70.2
Average of 30 foreign rivers	19.8	3.7	10.7	2.5	40.6	3.3	12.7	0.3	16.0	0.1	109.7

Source: [13].

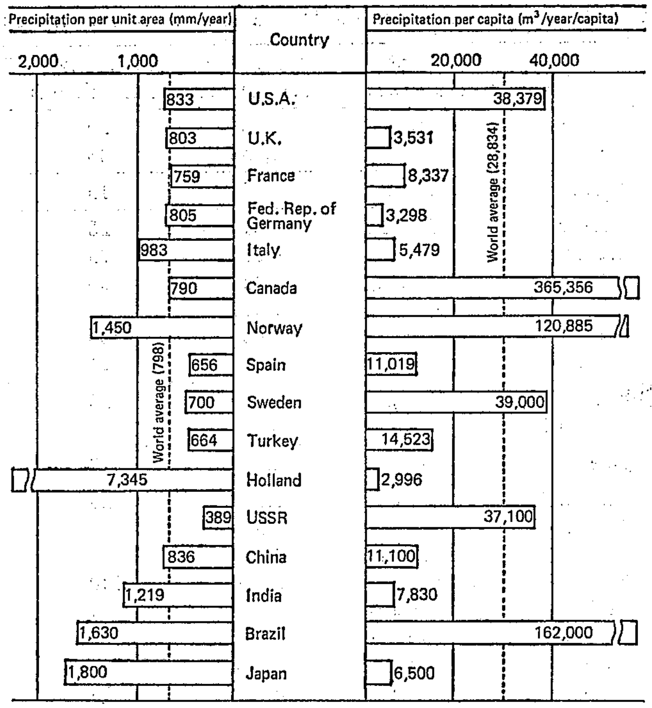
broadly classified into (1) intake, (2) conveyance, (3) purification, and (4) distribution.

From the qualitative point of view, water available from Japanese rivers contains little manganese and other inorganic matter (i.e., the water is soft), though having a rather high silicic acid content because of the widespread volcanic layer in this country (Table I). It is, therefore, suitable for drinking much of it being slightly acid and of good taste. The ready availability of natural water (raw water for water service) suitable for drinking caused the purifying function of waterworks to be virtually disregarded, and thus in the traditional waterworks technology of pre-modern Japan it achieved little technical progress with the result that only the intake, conveying, and distributing functions were considered to constitute a water supply system. In the development process of modern cities, before the organic content of sewage from households began to contaminate ground water noticeably and the need for water purification therefore increased in districts where fine ground water had been easily available, this circumstance kept the public hardly aware of even the need for waterworks as a fundamental urban facility and prevented their development and proliferation.

In the quantitative aspect, Japan has been blessed with abundant precipitation (or the maximum available water per unit area), with her order of ecosystems being formed in humid environment. However, the per capita precipitation in this country, though no smaller than in many other countries, is not appreciably greater than in other densely populated areas (i.e., advanced countries) either (Figure 1). Moreover in Japan, rice culture consuming large quantities of water had been highly developed already in pre-modern times, and accordingly the droughty water discharges of rivers had been almost fully exploited in more advanced agricultural districts by the dawn of the modern age. New water needs emerging in and after the Meiji years, including those for waterworks, often ran into serious conflict with water rights which had been established de facto (waterworks in Tokyo, where water requirements increased with the rapid expansion of population and industry, were no exception, but fortunately the substantial quantity of water secured by the supply systems built up in the Edo period kept them relatively immune from conflicts in their early years).

Japanese rivers, characteristically, are generally steep in grade and therefore

Fig. 1. Annual Precipitation in Different Countries



Source: [11].

form swift currents and have high run-off percentages. Furthermore, a large part of annual precipitation in Japan concentrates in the rainy and typhoon seasons. This large seasonal fluctuation in rainfall, coupled with the generally limited basin areas and swift flow of Japanese rivers, results in a poor flow-stabilizing function of the rivers and in a wide gap between their maximum and minimum flow rates. This means that, when the technique to stabilize the flow of large rivers with dams was not yet developed, only a small proportion of the total precipitation was available for steady use, with a major part of the floodwater flowing down unutilized into the sea. In addition, the big stream gradients reduce the effective capacity of dams, which are relatively quickly filled up with large quantities of mud and sand flowing into them, and the flow-stabilizing function of dams is thereby adversely affected (Table II). In the development of dam construction technology, exploitation of electric power resources was given priority, and it was not until after World War II that large dams began to be built for the purposes of water supply and flood control.

Since most Japanese cities are located on the alluvial plains or fans of rivers, where ground water is abundant, wells have been extensively used by urbanites from of old. As rivers are steep in grade, their surface water can be tapped with comparative ease, so that many cities did not have to depend on distant water resources. Although the droughty water discharges of rivers had been exhaustively used for irrigation, the quantity of urban water needs was far smaller than that of water for irrigation in pre-modern days. There were frequent disputes over

TABLE II

RIVER REGIME COEFFICIENTS OF MAJOR RIVERS IN THE WORLD

Country	River	Point of Measurement	Max. Flow Rate (m^3/Sec)	Min. Flow Rate (m^3/Sec)	River Regime Coefficient
France	Garonne	Toulouse	6,000	36	167
	Seine	Paris	1,652	48	34
U.K.	Thames	Teddington	103	13	8
Germany	Neckar	Heidelberg	4,819	28	172
	Weser	Baden	4,600	73	63
	Elbe	Magdeburg	4,430	100	43
	Oder	Breslau	2,450	22	111
	Rhine	Cologne	10,000	660	16
	Danube	Neuburg	2,100	125	17
U.S.	Ohio	Pittsburgh	12,000	33	364
	Missouri	Kansas City	20,830	277	75
Egypt	Nile	Cairo	12,000	400	30
Japan	Kitakami	Toyoma	5,570	25	223
	Mogami	Niibori	6,960	23	303
	Tone	Yattajima	13,000	45	287
	Shinano	Okozu	5,570	140	40
	Fuji	Kajikazawa	5,600	14	400
	Tenryū	Tenryūkyō	11,130	97	114
	Kiso	Inuyama	7,350	68	108
	Yodo	Hirakata	5,570	83	67
	Yoshino	Ikeda	26,200	83	3,160
	Watari	Gudo	13,000	17	765
	Chikugo	Kurume	9,000	28	323

Source: [9].

irrigation water rights, but urban dwellers had little doubted that nature would continue to supply them with sufficient water and scarcely recognized water as a social resource that should be developed by building huge facilities with enormous public investments. This lack of understanding immensely affected the spreading process of waterworks in modern Japan.

II. WATERWORKS IN PRE-MODERN JAPAN (WATERWORKS IN EDO)

The first waterworks in Japan is believed to be Kanda Jōsui built by the Tokugawa in 1590 when they established their headquarters in Edo. It was followed by waterworks in a number of other cities, constructed by feudal lords in the framework of castletown administration under the rule of the Tokugawa shogunate.

Construction of Kanda Jōsui, started almost simultaneously with the establishment of the Tokugawa headquarters in Edo, presumably was included in the blueprint for the capital city from the outset of its planning. Its inclusion in the construction program as one of the basic urban facilities, in spite of the absence of any predecessor in the history of Japanese cities, is believed to have been inspired by foreign missionaries staying in this country before her isolation from the rest of the world. In European cities, apart from the waterworks in ancient

Rome, partial water supply systems began to be constructed in or around the twelfth century, but it was not until between the fifteenth and sixteenth centuries that city-wide water networks came to be built in major cities such as London and Paris. This was about the time Western missionaries visited this country.

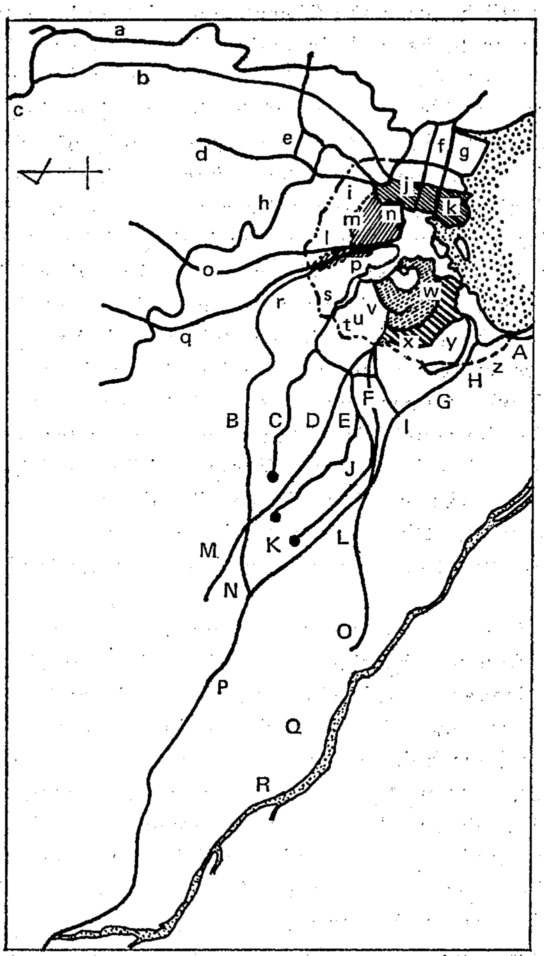
Of course, apart from the presumable influence of foreign missionaries, pre-Tokugawa warlords always had a vital interest in securing a supply of drinking and fire fighting water to their castletowns, but they often sought its source, mainly wells, within the town limits primarily for defense reasons. Construction of waterworks was intended for Edo from the very beginning of its planning presumably because a large part of the city was built on sandbanks and reclaimed land along the coast, where no good ground water was available, and further because Edo was projected from the outset as the capital city of the national government and expected to develop as a commercial, rather than military, town.

Construction of Kanda Jōsui, whose open conduit extended over twenty-three kilometers, was a vast project by the standards of those days. Its water sources were such spring-fed ponds as Inokashira-ike and Zempukuji-ike, which now constitute the care of well-known parks in urban Tokyo. Small streams flowing out of these ponds have been submerged into urban districts and are now hardly noticeable. They were much too small to meet the increasing water needs of Edo in later years.

For this reason, Tamagawa Jōsui, tapping the mainstream of the Tama River, was built from 1653 to 1654, followed by the construction of Kameari Jōsui, Aoyama Jōsui, Mita Jōsui, and Senkawa Jōsui, which, together with the first built Kanda Jōsui, constituted the water channelling and distributing network of Edo from then on. Out of the four later built waterworks, Kameari Jōsui derived water from the Furutone River, a tributary of the Tone River system, while Aoyama, Mita, and Senkawa Jōsui all branched out from Tamagawa Jōsui. Thus the skeleton of Tokyo's water supply system tapping mainly the Tama River system and partly the Tone River system was already formed in the age of the Edo waterworks and continued to serve the metropolis until recently.

Tamagawa Jōsui took in water from the mainstream of the Tama River with a weir built at Hamura, conveyed it to Yotsuya Ōkido, then the western limit of urban Edo, through a forty-three kilometer long open conduit inclined at about 1/500 and further into the city through a stone-built closed conduit, and distributed it through wooden piping to the residences of major samurai families and to the numberless water tanks for common use by townsmen. The conveyance and distribution of water wholly depended on natural flows and not on pressurizing devices. The waterworks had no curb stops but allowed water to flow freely, and had no purifying devices either. Although it was thus technically behind the waterworks of European cities in those days, Edo at the time had the world's biggest water supply system in terms of the population served. (By the end of the sixteenth century when all those six waterworks were completed, Edo's population is estimated to have reached 1 million or so, and a predominant part of urban Edo was covered by the six waterworks. Therefore the population served by the Edo water supply network is seen certain to have been the biggest in the world. See Figure 2.)

Fig. 2. Waterworks in the Edo Period (around 1715)



a. Furutone River
b. Kameari Jōsui
c. Koshigaya
d. Rikuu Road
e. Senju
f. Kameido
g. Sunamura
h. Ara River
i. Asakusa
j. Honjo
k. Fukagawa
l. Ueno
m. Hongō
n. Shitaya
o. Ōji
p. Koishikawa
q. Nakasendō (Road)
r. Itabashi
s. Sekiguchi
t. Ushigome
u. Ōkido
v. Yotsuya
w. Kanasugi
x. Aoyama Jōsui
y. Shibuya
z. Shirokane
A. Shinagawa
B. Senkawa Jōsui
C. Myōshōji Ryū (River)
D. Ōme Road
E. Zempukuji Ryū (River)
F. Sukemizu
G. Mita Jōsui
H. Meguro
I. Kitazawa
J. Kanda Jōsui
K. Inokashira
L. Kōshū Road
M. Tanashi
N. Hōya
O. Chōfu
P. Tamagawa Jōsui
Q. Fuchū
R. Tama River

Source: [13].

Underlying the successful construction of such large waterworks in those days was the circumstance that fairly advanced flood control and surveying techniques had been accumulated through fief administration by warlords as revealed by the flood control techniques embodied in Taikō Tsutsumi (Taikō Embankments) and Shingen Tsutsumi (Shingen Embankments) and by the nationwide land survey (*Bunroku kenchi*) conducted to facilitate separation of the samurai class from farmers. The fact that water channelling and distribution in such large waterworks wholly depended on the natural flow indicates the advanced level of surveying techniques achieved by that time. Because water-consuming rice culture had stimulated the development of irrigation and drainage techniques from of old and river boat transport had become a major mode of traffic in spite of the general swiftness of streams, Japan had a long tradition in low-water river work intended for stabilization of low-water discharges. However, her accumulation of traditional low-water techniques made possible the construction of waterworks in the early Edo period and other large-scale water supply projects, including the Tone River improvement project (involving rechannelling of the Tone and an eastward shift of its mainstream) accomplished in about the same period. These traditional techniques were systematized into what is known as the Kantō school (or the Ina school) of water utilization technology in that period.

Another noteworthy aspect of the Tamagawa Jōsui project was the solid foundation on which its basic conception stood. The routing of the water flow, drawn from the mainstream of the Tama River with the intake weir at Hamura and then led into urban Tokyo, has remained the skeleton of the Tokyo water service network for three centuries until the present days, though its channelling facilities have been changed. As regards the quantity of water supply, Tamagawa and Kanda Jōsui remained the only waterworks meeting the needs of Tokyoites until modern waterworks were completed for the city in 1898, even after the four others were disused in the first half of the eighteenth century partly because the development of wells made ground water of fair quality available for consumption.

III. PROCESS OF LEARNING MODERN WATERWORKS TECHNOLOGY

Under the modernization (=Westernization) policy of the new Meiji government, Western knowledge and experience were imported in all fields of technology. For the government, which put an end to shogunate rule existent since the seventeenth century by abolishing fiefs and establishing prefectures in 1871 thus institutionally realizing a modern unified state, implementation of public engineering works of all kinds, which would lay the foundation for utilization of national land in a modern way, was a particularly important task. Whereas railway, port and harbor, lighthouse, forestry conservation, and river improvement projects achieved significant progress throughout the Meiji period by the use of modern technology imported from the West, waterworks construction was one of the fields which attracted keen interest from very early in the era. Underlying this interest was the intrusion of germs from abroad, following the opening of the country to foreign intercourse in the last days of the Tokugawa rule, which brought about the frequent prevalence of cholera and dysentery in the early Meiji years, taking a heavy toll in lives, which greatly aroused public concern about sanitation. The contributions which the modernization of waterworks would make to preventing those water-borne diseases of the digestive organs were extensively known through the press, and Tokyoites became increasingly dissatisfied with the pollution of city water resulting from the deterioration of the former Edo waterworks, which in turn was due to their inadequate maintenance during the late Tokugawa years and to the decay of wooden piping.

There also were other circumstances which further enhanced public interest in the modernization of waterworks. A prerequisite for the revision of the unequal treaties with the Western powers, which was a top priority task for the Meiji government, was the accelerated modernization of Japan, which obviously involved the modernization of public utilities. Moreover, consular missions and other foreign residents often made requests and expressed fears about the prevailing state of public sanitation. Priority in the modernization process of Japan was afterwards shifted to building up the infrastructure for industry under the slogans of "Increase production and develop industry" and "Enrich the nation and strengthen the military," to the detriment of improved facilities to serve people's everyday needs, and this trend continued even after World War II. However, in those early years emphasis was still placed on disseminating the Western way of life and of redesigning cities in the Western style with a view to facilitating the intended revision of the unequal treaties. This circumstance, which is vividly reflected in a subsequent program of the City Replanning Commission of Tokyo, helps in an understanding of the strong interest in waterworks modernization of those days.

Thus there was great enthusiasm for construction of modern waterworks from very early in the Meiji period, and even private interests proposed many plans for waterworks construction, but none of them were realized, on account of financial difficulties, until Kanagawa Prefecture in 1887 built the Yokohama Waterworks, the first modern water supply system in this country.

Waterworks are hardly suitable for state projects because their beneficiaries are more or less confined to specific geographical areas, and were prescribed by the Waterworks Ordinance of 1880 to be constructed by municipalities. It seems that due to this nature of the waterworks projects their realization was somewhat delayed in spite of the enthusiastic interest in them at the state level. The Yokohama Waterworks, built by Kanagawa Prefecture as a local administrative body of the state before the institutionalization of local autonomy, was wholly financed by the national government largely because Yokohama, as one of the most important treaty ports, was the focus of foreign residents and the biggest inlet of infectious diseases from overseas. Consequently its relevance to the treaty revision and sanitation problems made it something more than a mere local waterworks in its meaning to the nation. However, this does not mean that the Yokohama Waterworks was solely the outcome of national concern on the part of the central government. In Yokohama, the water supply problem was far more serious than in Tokyo because its rapidly expanding urban area, developed on reclaimed land, was hardly able to depend on wells. Furthermore, unlike Tokyo where waterworks had been built in pre-modern days, a large part of clean water needs had to be bought from water mongers. As a result, the citizens of Yokohama were keenly aware of their need for water service—actually small-scale wooden-piped waterworks were built by traditional technology before the modern water supply system was established—and this awareness, together with the aforementioned circumstances, seems to have helped realize the construction of the Yokohama Waterworks as a state project.

Later on, following the organization of municipalities in 1888, the Waterworks Ordinance was enacted in 1890 as a legal basis of waterworks construction. Reflecting the then prevailing circumstances of public water supply, the ordinance at first provided for state subsidization of waterworks construction only in three prefectures (Tokyo, Osaka, and Kyoto) and five treaty ports (Yokohama, Kobe, Hakodate, Nagasaki, and Niigata), but other cities were successively made eligible

TABLE III

INCREASES IN POPULATION COVERED BY AND SUPPLY QUANTITY OF MAJOR WATER SERVICE SYSTEMS

City	Population Currently Served (1,000)					Maximum Daily Supply (1,000 m³)				
	1912	1930	1939	1970	1975	1912	1930	1939	1970	1975
Tokyo	1,430	4,763	5,837	8,449	10,485	242	1,083	1,330	4,954	5,647
Osaka	1,221	2,326	3,326	2,948	2,762	94	487	765	2,418	2,181
Yokohama	319	501	726	2,124	2,566	29	100	227	1,148	1,346
Nagoya	73	507	1,035	1,982	2,060	6	84	248	1,092	1,235
Kyoto	38	646	801	1,375	1,426	3	117	182	665	770
Kobe	218	681	920	1,161	1,176	33	142	179	550	578
Sapporo	—	—	111	655	1,039	—	—	29	196	359
Kawasaki	—	82	184	960	1,013	—	15	71	578	598
Fukuoka	—	137	216	783	900	—	17	27	284	399
Hiroshima	138	218	298	561	700	21	46	90	288	387
Sendai	—	87	124	485	582	—	18	27	172	236
Okayama	53	138	161	331	507	7	32	43	208	274
Nagasaki	154	162	178	401	409	13	32	34	104	140
Niigata	40	93	112	342	404	5	11	18	159	224

Sources: [1] [8].

for state subsidies afterwards. Increases of water supply of major water service systems are shown in Table III. The modern waterworks of Yokohama and others that followed it differed from earlier water supply systems in that they used iron pipes, in which pumping flow ran, and purifying facilities including sedimentation basins and filter beds. The use of iron pipes brought about major qualitative changes in water distribution and supply systems as it enabled pumping flow to run and be fed to individual households. In the aspect of equipment too, it meant the addition of such new elements as pressure pumps and curb stops, the latter at the ends of feed pipes. The pumping of water, furthermore, greatly contributed to improving the function of waterworks as a fire extinguishing facility and thereby tremendously influenced fire fighting organizations in cities. Since Japanese cities, because of the warm and humid climate of the country, had traditionally consisted of well ventilated and accordingly readily inflammable wooden buildings and had no waterworks with pumping flow in pre-modern times, they had developed a unique fire extinguishing techniques known as wrecking fire fighting, which did not heavily rely on waterworks. The importance of traditional waterworks in Edo as a means of fire fighting seems to have been so little recognized in spite of frequent conflagrations in the city that the disuse of four of its waterworks in the eighteenth century was said to have been triggered by the fantastic proposition of Muro Kyūsō, a Confucian scholar, that the waterworks had deprived soil of its humidity, dried the atmosphere, and thereby invited frequent fires.

The use of iron piping further is inseparable from the purifying function of waterworks, because distributing pipes can be completely sealed to prevent infiltration of filthy water into the lower reaches of the distribution system.

Among purifying facilities, sedimentation basins were not always required in Japan where raw water of satisfactory quality was available with comparative ease, but filter beds were indispensable for removal of bacteria, which, in a city where people live and engage in various activities, cannot be readily achieved by the natural purifying function of any river system. Without a filtering system, no waterworks can serve as a modern sanitary facility, and modern waterworks essentially differ from the traditional in this respect.

The Yokohama Waterworks was constructed to the design and under the supervision of British Royal Army engineer H. S. Palmer. In this period, foreign engineers hired by the Ministry of Interior also designed many of the waterworks in other cities, and among them were C. J. Van Doorn of the Netherlands and W. K. Burton of the United Kingdom, both playing important parts in the planning and designing of the Tokyo Waterworks. Most of these foreign engineers, who were accountable for the first generation of waterworks designing and planning in this country, well understood Japanese circumstances, wholeheartedly fulfilled their duties, and enthusiastically trained Japanese engineers. In Palmer's design of the Yokohama Waterworks, the hilltop Yamate Quarter among foreign residential districts was excluded from the coverage of the water service as the area was blessed with good well water and therefore, Palmer thought, did not justify a city water supply within the constraints of the budget and available materials. This episode illustrates the freedom of the Yokohama Waterworks project from flattery

TABLE IV

NUMBER OF FOREIGNERS EMPLOYED BY GOVERNMENT MINISTRIES

Year	Number of Foreigners Employed	Annual Salary per Foreign Expert Employed (¥)	Japan's Gross National Expenditure per Head (¥)
1885	155	3,288	21.0
1886	169	3,384	20.8
1887	195	3,384	21.1
1888	215	3,168	22.1
1889	220	3,084	24.2
1890	200	2,664	26.5
1891	170	2,832	28.3
1892	130	3,168	27.8
1893	104	2,904	29.3
1894	85	3,012	32.5
1895	79	2,928	37.3
1896	77	3,012	39.7
1897	92	3,288	46.2
1898	100	3,288	51.2

Sources: [14] [3].

to foreign powers and the conscience of the engineer who was well aware of local circumstances.

Notably, even in this period when there were as yet virtually no Japanese engineers versed in modern waterworks technology, the clients, water service authorities, well maintained their initiative over the foreign engineers they hired. The Kanagawa prefectural government had H. L. Mulder, an engineer employed by the Ministry of Interior, submit his expert opinion on Palmer's design for the Yokohama Waterworks, and took it into consideration in deciding on the construction plan. In the planning stage of the Tokyo Waterworks, the waterworks improvement committee of the city evaluated a number of alternative designs and further sought opinions of water service authorities of advanced nations before making its final decision. The enthusiasm of Japanese water service authorities in those days for information on waterworks technology is simply amazing even by present-day standards, and indicates that their waterworks projects were not mere imitations of technical achievements overseas, stimulated by the Westernization fever of the Meiji era, but stemmed from the endogenous needs of people's everyday life. The Japanese government highly evaluated the economic usefulness of the technical knowledge and experience of foreign engineers and paid them astoundingly generous remunerations (Table IV), but their place in the bureaucracy was no more than that of mere hired engineers, who were given no high-level screening or decision-making authority. Their function as technical consultants of high caliber was correctly appreciated, and this appreciation on the part of their employers made it possible to recruit first-class engineers, recognized as such even in their own countries, who on their part lived up to the expectations of the Japanese authorities.

Native engineers within the Japanese bureaucracy, who learned Western technology through their contact with foreign engineers on the job, were actively sent by the government to study in the West and, back home, assigned to leading positions in public work projects as technical pioneers. Some of them were concurrently appointed professors at imperial universities or technological institutes to play central roles in the introduction and assimilation of Western technology and in the education of their successors.

Foreign engineers employed by the Ministry of Interior, including Van Doorn and W. K. Burton, also served as Imperial University lecturers (or sometimes under other titles as the educational system was frequently amended in those days) to train Japanese engineers in an academic framework, but this role was in the meantime taken over by indigenous elite bureaucrat engineers, who constituted the second generation of waterworks designers in Japan. Among them were Kōi Furuichi, who concurrently was dean of the Engineering College, Tokyo University, director-general of the Civil Engineering Bureau, Ministry of Interior, and chief engineer of the Tokyo Waterworks construction project (he was one of the earliest bureaucrat civil engineers in Japan), and Eiji Nakajima, professor of Tokyo University and concurrently chief engineer of the municipal government of Tokyo, who directly supervised the construction of the Tokyo Waterworks until its completion. The latter, in particular, played an important part in the establishment of sanitary engineering in Japan and trained many successors as professors of sanitary engineering at Tokyo University. He himself designed and supervised the construction of many water supply and sewerage systems in Japanese and Korean cities in the first quarter of the twentieth century. In this way, universities and the technological sector of the bureaucracy were closely linked to each other, and the leadership of bureaucrat engineers long remained a characteristic aspect of civil engineering in Japan after its earliest phase in which it was largely dependent on foreign engineers. Since the construction and management of waterworks (and sewerage systems, too) were ascribed to the responsibilities of municipal government, a handful of sophisticated engineers pooled at universities and central government offices, of whom Nakajima was a typical example, undertook the initial designing of those projects, and local engineers took charge of the execution of construction plans and maintenance and management of waterworks under the guidance of those higher-level engineers from the central authority. This pattern of division of functions was preserved until quite recently. In the development of industrial technology, designing and developing functions were in many cases performed by a sector of the manufacturing enterprises, with the result that designing techniques remained undifferentiated from manufacturing techniques, the former having a tendency to be subordinate to the latter. This was in sharp contrast to the circumstance of bureaucrat-dominated civil engineering, especially in its water supply and sewerage sector. Whereas the formation of this hierarchical structure in civil engineering can be largely explained by the substantial accumulation of traditional techniques nation-wide, which took charge of the executional phase of projects planned and designed by advanced techniques imported from the West, this circumstance of civil engineering tech-

TABLE V

NUMBER OF WELLS TAPPING THE TAMAGAWA AND KANDA WATERWORKS IN THE EARLY MEIJI ERA

Year	Number of Wells	Year	Number of Wells	Year	Number of Wells
1875	5,800	1878	6,510	1881	6,728
1876	6,307	1879	6,631	1882	6,734
1877	6,233	1880	6,725	1883	6,803

Source: [21].

nology at the same time undeniably retarded the modernization of the construction industry in this country.

When the Yokohama Waterworks was built, all principal materials needed for modern waterworks, such as iron pipes, pumps, joints, and other accessory items, had to be imported, but notably, private entrepreneurs were eager from very early times to produce these items in Japan. Cast iron pipes began to be manufactured in this country by the 1880s, and the local production of iron pipes for waterworks gradually made progress in the first quarter of the twentieth century, although hasty encouragement of local production without adequate development of technology sometimes invited delivery of defective products. This gave rise to a case of bribery between the municipal water service of Tokyo and Japan Cast Iron Company (commonly known as the iron pipe scandal). By the early 1910s, pumps and water gauges also began to be produced in Japan. Noteworthy in this connection is the formulation of standards on iron pipes for waterworks by the Waterworks Council in 1914. They were among the earliest of industrial standards stipulated in this country, and this standardization made important contributions to the subsequent progress of industrialization.

IV. CONSTRUCTION AND DEVELOPMENT OF TOKYO WATERWORKS

The downfall of the Tokugawa shogunate invited dispersion of the ruling family's vassals and consequently a transient decrease in Tokyo's inhabitants, but the nation's capital quickly recovered its population in a short period thereafter and set itself on the track of rapid development. What met the water needs of Tokyoites for three decades following the Meiji Restoration were the former Edo waterworks inherited by the new government and wells in various parts of the urban area (Table V). While Tokyo's population of a little less than 800,000 early in the Meiji period approximately doubled by 1899 when its improved waterworks were completed, Senkawa Jōsui, out of the former Edo waterworks, was restored in 1880 and Azabu Suidō was branched out from Tamagawa Jōsui. All these projects were undertaken by private interests to meet the increasing demand for water, and consisted of expansions of existing waterworks by traditional technology.

Meanwhile, because of the frequent prevalence of epidemics, there was grave concern, both in and out of the government, over the sanitary conditions of waterworks with extensive recognition of the need to improve them fundamentally by modern waterworks technology. Dutch engineer Van Doorn employed by the Ministry of Interior, in accordance with the instruction of the government, submitted a proposal regarding the improvement of waterworks in Tokyo in 1874 and a blueprint in 1875. Toward the end of 1876, a waterworks improvement committee was established in the Tokyo prefectural government, and began systematically to study the improvement plan, based on Van Doorn's design. In 1875, the Metropolitan Police Board of Tokyo examined the extent of pollution of Tamagawa Jōsui and Kanda Jōsui. In the previous year, the water quality of the two major supply systems had been checked by the Ministry of Education, followed by further scientific examinations by the Sanitary Bureau of the Ministry of Interior and Tokyo University. The findings of all these surveys indicated that, although the quality of raw water at its points of intake was highly satisfactory, pollution through the rotten parts of the wooden piping seriously affected its quality to make mostly unpotable by the time it reached its terminal outlets, and accordingly pointed to the urgent need to improve the waterworks by replacing the wooden with iron pipes. In those years, Japan suffered sporadic nationwide epidemics of cholera in 1877, 1879, 1882, and 1886, apart from a pre-Meiji extensive spread of the disease in 1858. In particular, the prevalence of cholera in 1886 took a nationwide toll of 110,000 lives, and its involvement in the upper reaches of the Tama River, Tokyo's major water reservoir, aroused grave concern among the citizens of Tokyo over the suspected contamination of water supplied to them and thereby helped accelerate the implementation of the waterworks improvement program. In 1887, at the initiative of Eiichi Shibusawa, influential businessman proposed the operation of a modern waterworks, based on a blueprint by Palmer who had designed the Yokohama Waterworks. Reflecting this and other related moves, the government in 1890 promulgated the Waterworks Ordinance and approved the design of the improved Tokyo Waterworks.

In view of the fact that the prevalence of cholera in 1886 had drawn the attention of Tokyoites to their water source, the prefectural government of Tokyo, out of the need to strengthen its maintenance and control of the source of water supply to the nation's capital, decided to place under its rule the three Tama districts, then belonging to Kanagawa Prefecture, and in 1893 succeeded in doing so. Since the three districts constituted a center of civil rights movements in those days, their transfer to Tokyo Prefecture was regarded as representing the national government's intention to suppress the movements and called forth a strong campaign to oppose it, which was an unexpected by-product of the waterworks problem.

In spite of the early start in planning for the modernization of the waterworks in Tokyo, it was not until 1893 that the design approved in 1890 was actually put into execution, nearly two decades after Van Doorn had submitted his proposal for improvement. The delay was attributable in part to the project's vast scale viewed by the standard of those days, for it planned to serve a population of 1 million. This situation inevitably called for prudence in formulating the executional plan. However, the delay was due more to the difficulty of raising funds as smaller landowners, who had become taxpayers under a new land tax system in the framework of various reforms implemented since early Meiji years to modernize the nation, had impressions of being overtaxed. The costs of waterworks projects are usually levied on their beneficiaries, who can be identified with relative definitude, and subsequent water supply systems in Japan also came to be operated by local public enterprises on a self-sustaining basis, primarily dependent on water charges collected. However, in the earlier part of the Meiji era, while citizens were increasingly aware of the need for modern waterworks on the one hand, there was serious social unrest aroused by drastic reforms and popular discontent about what was considered too heavy taxation on the other hand. It was therefore difficult to levy a new tax to finance the vastly expensive waterworks project. Meanwhile, the City Replanning Commission of Tokyo was working on a program to remodel Tokyo befitting its status as the capital of a modern unified nation, which would involve the modernization of waterworks as well. Eventually in 1888, the Tokyo City Replanning Ordinance, which among other things provided for special financing of the redevelopment project was promulgated as a state law (Imperial Ordinance No. 62 of 1888), and construction of modern waterworks in Tokyo would thus be undertaken in the framework of this urban revamping program. This ordinance, too, was formulated only after strong opposition by the Senate, reflecting the interests of the landowner class, was overridden.

The plan of the Tokyo Waterworks finalized in 1890 by the Tokyo City Replanning Commission was based on W. K. Burton's design and supplemented with Palmer's proposal for a water company as well as opinions sought from experts in the Belgian and German water bureaus. The envisaged water supply system would serve a population of 1.5 million with a maximum daily supply of 166,000 cubic meters (or a per capita daily supply of 111 liters at the maximum or 75 liters on an average). It would use the facilities of the existing Tamagawa Jōsui for taking in and conveying water from the Tama River, which was led through a new concrete-built channel to a purifying plant having a sedimentation basin and slow filter. The whole area of the city was divided into higher and lower water supply districts, and the higher districts were directly pressure-supplied with water pumped out from the plant, while two water supply stations were established for feeding the lower districts, with clean water flowing down by gravity from the purifying plant to the supply stations, from where water would be pressure-supplied to individual households. This plan was implemented substantially as it was mapped out, though with minor modifications as to the location of the purifying plant and supply stations. The initial phase of the project was completed in 1899, and the whole planned coverage of the water service began to be supplied, with the old waterworks discontinuing its operation at the same time.

The construction of the waterworks made fair progress with little, if any, technical trouble, although there was some delay in the acquisition of installation sites and some of the locally manufactured iron pipes, which were intended for the water distribution network, proved faulty, leading to the disclosure of a bribery scandal. However, by 1899 when the initial phase of the project came to completion, the population of Tokyo City had surpassed the number of inhabitants the waterworks had been supposed to serve, and the urban area had also outgrown the planned geographical coverage of the water service network. In view of these circumstances, the capacity of the purifying plant was expanded in 1908 to serve, as it was planned, a population of 2 million with a maximum daily quantity of 223,000 cubic meters (or 167 liters per head). Until that time, water had been derived from the old Tamagawa Jōsui, but a further expansion of the water supply could not readily depend on an increased intake of the surface water of the river in the dry season because of the limitation of established water rights, and instead had primarily to rely on the development of seasonal surplus water by building reservoirs. The quick expansion of Tokyo made it increasingly difficult to exploit new water resources. The augmentation of the water supply thereafter always lagged behind the growth of the water-needing population and the expansion of the urban area. Not only did the population grow faster than expected but also, the development of additional water resources was retarded by the shortage of funds and materials, the impact of the Kantō Earthquake and, in wartime, the concentration of financial and material resources in industrial infrastructures at the sacrifice of everyday utilities including waterworks.

Briefly to trace the expansion of water service during the years that followed, in the first stage the intake at Hamura was increased and channelled through a new conduit to reservoirs (at Murayama and Yamaguchi) built in valleys between nearby hills to augment the available quantity of water. This project was launched in later Meiji, but was delayed by the Kantō Earthquake and not completed until 1937. In the meantime, towns around Tokyo, which had rapidly developed as a result of the post-earthquake migration of the population to the suburbs thereby constituting new urban districts continuous from the traditional territory of Tokyo, were merged into Tokyo City in 1932, together with their small waterworks which were also integrated with the water service network of the nation's capital. Those minor waterworks derived their water from different sources, some dependent on raw water from the waterworks of Tokyo City, others tapping the lower reaches of the Tama River and still others drawing ground water. However, many households in those satellite cities relied on wells and the proportion of the population supplied with city water service was accordingly small. This was because all those new urban districts had emerged from farming areas so rapidly that their waterworks were constructed after their urbanization.

In the second phase of the expansion program, it was planned to intercept the mainstream of the Tama River with a large dam and discharge the blocked volume of water in the dry season. The extra quantity of water made available by this flow control would be tapped at the Hamura intake and channelled to the Murayama and Yamaguchi reservoirs. The project, mapped out in the middle of 1920s in preparation for Tokyo's population to eventually reach 10 million, won official approval in 1936, but its implementation was interrupted by the wartime shortage of materials. It was not until 1957 that the Ogōchi Reservoir was finally completed in its framework, followed by the completion of the Higashimurayama Purifying Plant and other major facilities some time later. With the completion of the Higashimurayama Plant, the function of the Yodobashi Purifying Plant which had served the modern waterworks system of Tokyo since its founding in the Meiji period was incorporated into the new plant.

In the meantime, as a stopgap measure, conveying and distributing facilities

TABLE VI
WATER SUPPLY PERVASION IN SUBURBAN CITIES OF GREATER TOKYO

Cities	Year or Establishment	Rate of Pervasion (%)				
		1950	1953	1955	1961	1975
Hachiōji	1928	42		35	56	98
Tachikawa	1952		39	64	90	99
Musashino	1954			18	66	100
Mitaka	1959				42	100
Ōme	1927	69		60	81	100
Fuchū	1958				53	100
Chōfu	1959				38	100
Koganei	1958				43	99

Sources: [12] [19].
Notes: 1. The year of establishment is the year in which partial water supply was started in the pertinent city.
2. The rate of pervasion=the population currently supplied with water/the total population of the administrative district.

for water derived from the Edo and Sagami River systems were built in the middle of 1920s.

Tokyo's waterworks since the Edo period had primarily tapped the Tama River system, which, however, became no longer able to meet by itself the city's water needs which had enormously expanded as a result of its population explosion. In the third phase of the water service expansion program, therefore, an additional supply was sought from the Tone, the biggest river running through the Kantō Plains. The idea preceded World War II, but it was not formulated into a specific project until after the war. The quantity of water already available from the Tone River had been fully utilized, and conflicting interests made it difficult to equitably distribute even the additional volume that could be made available by damming. In view of this situation, Water Resources Development Promotion Act was enacted in 1961 to ensure a deliberate adjustment of water demand and supply, and the Tone River would be developed as one of designated river systems under the new law. The Water Resources Development Corporation, established in 1962 to engage in multipurpose development of water resources, constructed the Yagisawa and Shimokubo dams in the upper reaches of the Tone and a weir at its mouth, and a part of the additional volume of water thereby made available was supplied to the Tokyo water service network, whose present basis was then established, mainly dependent on the Tama and Tone river systems. Water was tapped at an intake dam (the Tone River Salinity Barrier) built in Gyōda City, Saitama Prefecture, in the middle reaches of the Tone, led to the Ara River through the Musashi Channel, let flow along the natural stream of the Ara River, again tapped at the Akigase Weir, and further led to the Higashimurayama Purifying Plant by way of the Asaka Channel. Part of the water path was put into use in 1965, and the whole new water service system was completed in 1968.

Incidentally, most of the waterworks in the satellite cities on the Musashino Tableland, whose urban districts are continuous to those of the twenty-three wards (known as *ku*) of central Tokyo, were only recently built (Table VI). For instance in Tachikawa City, which had been quickly urbanized in the middle of the 1920s along with the establishment therein of the defunct Imperial Army's airfield and the war industry including Nakajima Aircraft Works, the supply of city water was not started until 1952, and before that every household had drawn drinking water from its own shallow well. The waterworks of Musashino and Mitaka cities on the outskirts of Tokyo, where development of residential quarters had rapidly progressed after the Kantō Earthquake, did not enter service until 1954 and 1959, respectively. (Musashino has within its limits the source of Kanda Jōsui, the earliest built of the old Edo waterworks.)

In any of these cities, where shallow wells could readily provide ground water of good quality, citizens took no serious interest in building waterworks before sewage from households began to noticeably contaminate well water along with the progress of urbanization. In Tachikawa, a proposal to build a waterworks was triggered by the pollution of ground water by aircraft fuel which had spilled out of a broken pipeline in the airfield of the U.S. Air Force. All the waterworks these municipalities eventually built drew raw water from deep wells and purified it before supplying it to consumers.

CONCLUSION

Water obviously is one of the fundamental resources for urban life and industrial activity. Since ancient times the availability of a water supply and waste water discharge has been one of the most vital factors determining the location and conditioning the development of cities. The advancement of waterworks technology, by making the tapping of water resources far away feasible, has increased the freedom of urban location, and eased the restrictions on the spatial size of cities. At the same time, cities have been systematically integrated into the hydrological cycle through their water supply and sewerage facilities. Water, which is indispensable to human life, moves in a natural cycle of precipitation, flowing down, and evaporation (the hydrological cycle), on whose basis is maintained the order of ecosystems. Human activities obviously cannot be independent of the natural cycle of water or the order of ecosystems. While in a rural area man tends to utilize this natural asset through the individual who has a more direct link with its natural cycle, in an urban environment which is more segregated from nature because of its greater density of human dwellings, man requires more artificial facilities for common use. From this point of view, urban planning means planning the utilization of land to enable people to live densely in a limited area, and planning facilities for their common use. In this context, the water supply and sewerage systems, which position a city in a given natural water cycle and constitute a cyclic process of their own in the city, can be regarded as the most fundamental urban facility.

To look back on the history of the development of waterworks technology and the construction of water service systems in Japan, large-scale waterworks were already built before the modern age (those in Edo). Although the subsequent delay in Japan's industrial revolution owing to her self-imposed isolation from the rest of the world prevented her own waterworks technology from being developed until modern technology was imported from the West after the Meiji Restoration, the switch to, and the later assimilation of, Western technology seems to have been achieved in a generally smooth process. Construction of modern waterworks was one of the fields which were the earliest to attract public interest in the growing enthusiasm of the early Meiji period to build modern cities. Nevertheless, in the subsequent process of urbanization and industrialization, the construction of waterworks always lagged behind other aspects and the coverage of public water service remained at a relatively low level until recently (see Appendix Table III). This is even more true with sewerage, which has constituted only a negligible segment of all public engineering works in the development process of modern cities in Japan.

In present day Japan, it is often pointed out that the build-up of social capital is generally inadequate relative to the rise in income level, i.e., the stock lags behind the flow, and water service facilities have never constituted a dominant part of this relatively poor social capital of the nation (see Appendix Table II).

Few Japanese cities are deliberately and clearly distinguished from rural areas by urban facilities, and many have sprawled into surrounding rural districts ahead of urban planning and the construction of urban facilities, particularly of waterworks and sewerages.

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APPENDIX

INCREASE IN CAPITAL STOCK

Year	Sum of Gross Capital Stock				
	Total	Harbors	Roads	Riparian Works	Waterworks
1877	811,038	24,863 (3.1)	190,301 (23.5)	570,611 (70.3)	25,263 (3.1)
1882	916,890	27,186 (3.0)	232,909 (25.4)	626,320 (68.3)	30,475 (3.3)
1887	1,041,727	31,777 (3.1)	285,712 (27.4)	692,237 (66.5)	32,001 (3.1)
1892	1,192,790	36,921 (3.1)	347,356 (29.1)	774,087 (64.9)	34,426 (2.9)
1897	1,386,580	43,789 (3.2)	434,139 (31.3)	871,639 (62.9)	37,013 (2.7)
1902	1,698,567	64,654 (3.8)	573,370 (33.8)	1,007,664 (59.3)	52,879 (3.1)
1907	1,981,163	94,775 (4.8)	717,639 (36.2)	1,096,422 (55.3)	72,327 (3.7)
1912	2,468,976	130,423 (5.3)	963,750 (39.3)	1,252,298 (50.7)	122,505 (5.0)
1917	2,961,861	169,939 (5.7)	1,193,345 (40.3)	1,426,989 (48.2)	171,588 (5.8)
1922	3,401,374	213,689 (6.3)	1,363,611 (40.1)	1,563,274 (46.0)	260,800 (7.7)
1927	4,238,786	301,839 (7.1)	1,801,604 (42.5)	1,721,401 (40.6)	413,942 (9.8)
1932	5,594,201	444,009 (7.9)	2,651,179 (47.4)	1,913,516 (34.2)	585,497 (10.5)
1937	7,250,938	630,486 (8.7)	3,668,161 (50.6)	2,243,780 (30.9)	708,511 (9.8)

Source: [15].

APPENDIX TABLE I

THE MAXIMUM AVAILABLE WATER RESOURCES AND ITS UTILIZATION RATIOS

Region	Maximum Available Water in Droughty Year (bil. m^3/Year)	Utilization Ratio (%)	
		1975	2000
Hokkaidō	49.31	12	19
Tōhoku	72.88	26	36
Kantō	37.65	47	74
Tōkai	40.34	23	37
Hokuriku	20.64	23	33
Kinki	26.16	37	50
Chūgoku	27.65	28	39
San'in	10.73	16	22
San'yo	16.92	35	50
Shikoku	19.19	19	29
Kyūshū	38.88	25	42
Northern	12.19	45	72
Southern	26.69	16	28
Okinawa	1.12	21	55
National total	333.82	26	39

Source: [6].

Note: The utilization ratio of water resources is the ratio of requirements (on an intake basis) in 1975 or projected requirements in 2000 to the maximum available water resources in a droughty year.

TABLE II

OF CIVIL ENGINEERING

(In 1930 prices, 1,000 yen)

Increment of Gross Capital Stock (in Five Years)				
Total	Harbors	Roads	Riparian Works	Waterworks
—	—	—	—	—
105,852	2,323(2.2)	42,608(40.3)	55,709(52.6)	5,212(4.9)
124,837	4,591(3.7)	52,803(27.4)	65,917(52.8)	1,526(1.2)
151,063	5,144(3.4)	61,644(40.8)	81,850(54.2)	2,425(1.6)
193,790	6,868(3.2)	86,813(44.8)	97,552(50.3)	2,587(1.3)
311,987	20,865(6.7)	139,231(44.6)	136,025(43.6)	15,866(5.1)
282,596	30,121(10.7)	144,269(51.1)	88,758(31.4)	19,448(6.9)
487,813	35,648(7.3)	246,111(39.0)	155,876(32.0)	49,768(10.2)
492,885	39,516(8.0)	229,595(46.6)	174,691(35.4)	49,083(10.0)
439,513	43,750(10.0)	170,266(38.7)	136,285(31.0)	89,212(20.3)
837,412	88,150(7.1)	437,993(52.3)	158,127(18.8)	153,142(18.3)
1,355,415	142,170(10.5)	849,571(62.6)	192,115(14.2)	171,555(12.7)
1,656,737	186,477(11.3)	1,016,982(61.4)	330,264(19.9)	123,014(7.4)

APPENDIX TABLE III

SPREAD OF PUBLIC WATER SERVICE IN JAPAN

Year	National Population (1,000) (A)	No. of Proj-ects	Planned Max-imum Water Supply/Day (m^3)	Planned Coverage (1,000 Persons) (B)	Current Coverage (1,000 Persons) (C)	Water Supply Pervasion Ratio (%)	
						B/A	C/A
1887	38,703	1	5,720	70		0.2	
1890	39,902	4	17,594	193		0.5	
1895	41,557	5	68,834	803		1.9	
1900	43,847	7	88,742	1,017		2.4	
1905	46,620	9	159,388	1,699		3.6	
1910	49,184	20	202,225	2,131		4.3	
1915	52,752	38	873,695	7,192		13.6	
1920	55,391	51	1,201,725	9,759		17.6	
1925	59,179	106	1,585,512	12,256		20.7	
1930	63,872	198	2,380,132	14,976		23.4	
1935	68,662	277	3,200,282	19,970		29.1	
1940	71,400	339	4,342,820	24,150		33.8	
1945	72,200	357	4,783,864	25,110		34.8	
1950	83,200	383	5,098,434	26,087		31.4	
1955	89,276	485	6,562,164	28,609		32.0	
1960	93,419	820	10,462,200	37,832		40.5	
1965	98,275	1,416	21,483,000	75,787	56,402	77.1	57.4
1970	103,720	1,662	34,409,000	96,507	72,361	93.0	69.8
1975	112,279	1,828	47,751,000	112,107	88,065	99.8	78.4

Sources: [13] [8].
Note: Private or small-scale water supply systems are not counted.