THE UNITED NATIONS UNIVERSITY

UNIVERSITÉ DES NATIONS UNIES

Project on Technology Transfer, Transformation, and Development: The Japanese Experience

Projet sur l'expérience japonaise en matière de transfert, transformation et développement de la technologie

Distribution: Limited

HSDP-JE Series

The JE project is co-ordinated by UNU Project Co-ordinator Dr. Takeshi Hayashi, with the support of the Institute of Developing Economies, Address: UNU Project on Technology Transfer, Transformation, and Development: The Japanese Experience, c/o Institute of Developing Economies, 42 Ichigaya-Honmuracho, Shinjuku-ku, Tokyo 162, Japan. Tel: (03) 353-7501. Cable: AJIKEN TOKYO.

The United Nations University: 29th Floor, Toho Seimei Building, 15-1, Shibuya 2-chome, Shibuya-ku, Tokyo 150, Japan. Tel.: (03) 499-2811; Telex: J25442; Cable: UNATUNIV TOKYO

Printed in Japan

ISBN 92-808-0240-2
ISSN 0379-5780

HSDRJE-29/UNUP-240

THE DEVELOPMENT OF WATERWORKS IN JAPAN

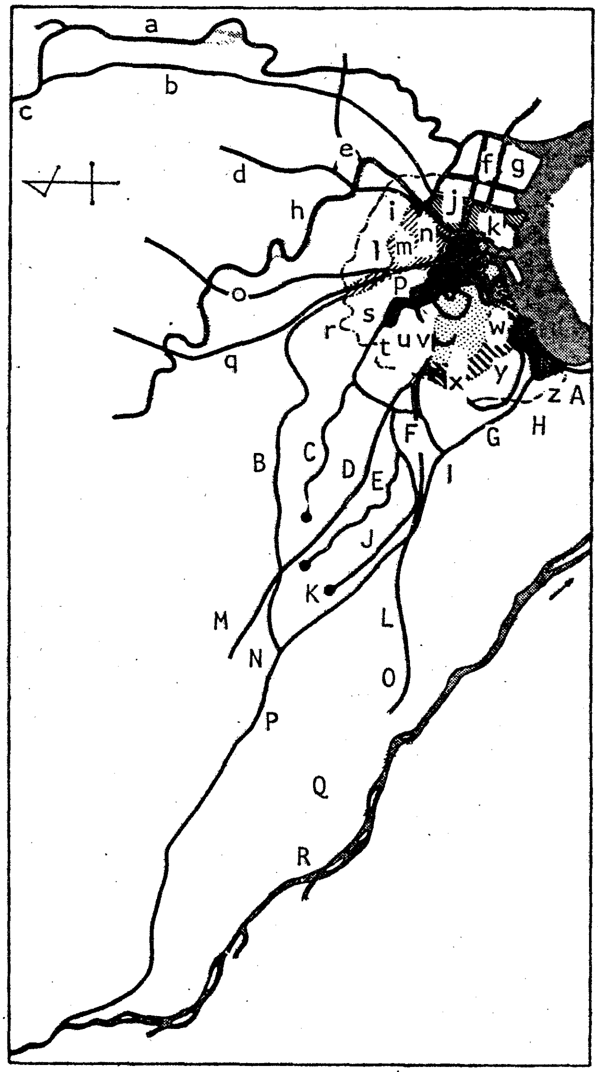
Nobuhiko Kosuge

Deputy Director, Planning Division
Planning and Co-ordination Bureau
National Land Agency
Tokyo, Japan

PRINTED ON RECYCLED PAPER

CONTENTS

Waterworks in the Edo Period (around 1715)



a - Furutone R.
b - Kameari Jōsui
c - Koshigaya
d - Rikuu Kaidō
e - Senju
f - Kameido
g - Sunamura
h - Ara R.
i - Asakusa
j - Honjo
k - Fukagawa
l - Ueno
m - Hongō
n - Shitaya
o - Ōji
p - Koishikawa
q - Nakasendō
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
D - Ōme Kaidō
E - Zempukuji Ryū
F - Sukemizu
G - Mita Jōsui
H - Meguro
I - Kitazawa
J - Kanda Jōsui
K - Inokashira
L - Kōshū Kaidō
M - Tanashi
N - Hōya
O - Chōfu
P - Tamagawa Jōsui
Q - Fuchū
R - Tama R.

Source: Nippon Suidō Kyōkai, Nippon Suidō-shi, Sōron-hen.

I. INTRODUCTION

Water is one of the fundamental resources for urban life and industrial activities. Since ancient times the availability of water supply and sewerage outlets has been one of the most vital factors determining the location and conditioning the development of cities. The advancement of waterworks technology, by making feasible the tapping of water resources far away, has increased the freedom of urban location from any particular water source and eased the restrictions on the spatial size of cities. At the same time, cities have become more closely linked to drainage texture, as they have been systematically integrated into the cyclic process of water through their water supply and sewerage facilities. Water, which is indispensable to human life, moves in a natural cycle of rain, flow, and evaporation (the hydrologic cycle), on which 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 an individual, more direct link with its natural cycle, in an urban environment that is less tied to 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 drainage texture and constitute a cyclic process of their own in the city, can be regarded as the most fundamental urban facility.

Looking back on the history of the development of waterworks technology and the construction of water service systems in Japan, we see that

Table 1. Spread of Public Water Service in Japan

Year	National population (in thousands) (A)	No. of projects	Planned maximum water supply/day (in m^2)	Planned coverage (population in thousands) (B)	Current coverage (population in thousands) (C)	Ratios of coverage (in %)	
						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		42.0	
1960	93,419	820	10,462,200	37,832		40.5	
1965	98,275	1,416	21,483	75,787	56,402	77.1	57.4
1970	103,720	1,662	34,409	96,507	72,361	93.0	69.8
1975	112,279	1,828	47,751	112,107	88,065	99.8	78.4

Sources: Nippon Suidō Kyōkai, Nippon Suidō-shi, Sōron-hen (English translations of the titles of this and other references in Japanese are given in the appended list of references, unless they immediately follow, in brackets, the original Japanese titles in the main text); Kōsei-shō [Ministry of Public Health and Welfare], Suidō Tōkei [Statistics on waterworks].

Note: Private or small-scale water supply systems are not counted.

large-scale waterworks were already built before the modern age (those in Edo, present-day Tokyo). Although the subsequent delay in the industrial revolution owing to Japan's self-imposed isolation from the rest of the world prevented her from developing her own waterworks technology until modern technology was imported from the West after the Meiji Restoration in 1868, the switch to, and the later assimilation of, Western technology seems generally to have been achieved smoothly. Construction of modern waterworks was one of the fields that first attracted public interest in the early Meiji ambience of growing enthusiasm for building modern cities. Nevertheless, the construction of waterworks always lagged behind other aspects of the process of urbanization and industrialization, and the extent of public water service remained at a relatively low level until recently. This is even more true with sewerage, which has constituted only a negligible segment of all public engineering works in the development of modern

Table 2. Increase in Capital Stock of Civil Engineering Products (in Terms of Value in 1930, in Thousand Yen)

Year	Sum of gross capital stock					Increment of gross capital stock (in 5-year intervals)				
	Total	Ports and harbours	Roads	Flood control	Water supply and drainage	Total	Ports and harbours	Roads	Flood control	Water supply and drainage
1877	811,038	24,863	190,301	570,611	25,263	—	—	—	—	—
		(3.1)	(23.5)	(70.3)	(3.1)	(-)	(-)	(-)	(-)	(-)
1882	916,890	27,186	239,909	626,320	30,475	105,852	2,323	42,608	55,709	5,212
		(3.0)	(25.4)	(68.3)	(3.3)		(2.2)	(40.3)	(52.6)	(4.9)
1887	1,041,727	31,777	285,712	692,237	32,001	124,837	4,591	52,803	65,917	1,526
		(3.1)	(27.4)	(66.5)	(3.1)		(3.7)	(27.4)	(52.8)	(1.2)
1892	1,192,790	36,921	347,356	774,087	34,426	151,063	5,144	61,644	81,850	2,425
		(3.1)	(29.1)	(64.9)	(2.9)		(3.4)	(40.8)	(54.2)	(1.6)
1897	1,386,580	43,789	434,139	871,639	37,013	193,790	6,868	86,813	97,552	2,587
		(3.2)	(31.3)	(62.9)	(2.7)		(3.2)	(44.8)	(50.3)	(1.3)
1902	1,698,567	64,654	573,370	1,007,664	52,879	311,987	20,865	139,231	136,025	15,866
		(3.8)	(33.8)	(59.3)	(3.1)		(6.7)	(44.6)	(43.6)	(5.1)
1907	1,981,163	94,775	717,639	1,096,422	72,327	282,596	30,121	144,269	88,758	19,448
		(4.8)	(36.2)	(55.3)	(3.7)		(10.7)	(51.1)	(31.4)	(6.9)
1912	2,468,976	130,423	963,750	1,252,298	122,505	487,813	35,648	246,111	155,876	49,768
		(5.3)	(39.3)	(50.7)	(5.0)		(7.3)	(39.0)	(32.0)	(10.2)
1917	2,961,861	169,939	1,193,345	1,426,989	171,588	492,885	39,516	229,595	174,691	49,083
		(5.7)	(40.3)	(48.2)	(5.8)		(8.0)	(46.6)	(35.4)	(10.0)
1922	3,401,374	213,689	1,363,611	1,563,274	260,800	439,513	43,750	170,266	136,285	89,212
		(6.3)	(40.1)	(46.0)	(7.7)		(10.0)	(38.7)	(31.0)	(20.3)
1927	4,238,786	301,839	1,801,604	1,721,401	413,942	837,412	88,150	437,993	158,127	153,142
		(7.1)	(42.5)	(40.6)	(9.8)		(7.1)	(52.3)	(18.8)	(18.3)
1932	5,594,201	444,009	2,651,179	1,913,516	585,497	1,355,415	142,170	849,571	192,115	171,555
		(7.9)	(47.4)	(34.2)	(10.5)		(10.5)	(62.6)	(14.2)	(12.7)
1937	7,250,938	630,486	3,668,161	2,243,780	708,511	1,656,737	186,477	1,016,982	330,264	123,014
		(8.7)	(50.6)	(30.9)	(9.8)		(11.3)	(61.4)	(19.9)	(7.4)

Source: Kazushi Okawa et al., ed., Chōki Keizai Tōkei - 3. Shihon Keisei [Long-term economic statistics - 3. Capital formation].

cities in Japan.

Still, 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. Water service facilities have never constituted a dominant part of this relatively poor social capital of the nation.

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 construction of urban facilities, particularly of waterworks.

In this paper, I would like to review the history of waterworks construction in Japan, especially in Tokyo, and discuss how waterworks and urban development condition each other.

II. DISTINCTIVE FEATURES OF WATER RESOURCES IN JAPAN

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

From the qualitative point of view, waters available from Japanese rivers contain little manganese and other inorganic matters (i.e., the waters are "soft"), though they have rather high silicic acid contents because of Japan's widespread volcanic layer and are suitable for drinking. Many of them are slightly acid and taste good. The ready availability of natural water (raw water for water service) suitable for drinking caused the purifying function to be virtually disregarded and to make little technical progress in the traditional waterworks technology of premodern Japan, 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 organic sewage from households began to contaminate subterranean water noticeably, thereby increasing the need for water purification in districts dependent on underground water, the ready supply of good drinking water left the public hardly aware of even the need for waterworks themselves as fundamental urban facilities and prevented their development and proliferation.

Quantitatively, Japan has been blessed with abundant precipitation (or the recharge storage of water per unit area), with her order of ecosystems being formed in a humid environment. However, the

Table 3. Water Analyses of Japanese and Foreign Rivers (in 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: Nippon Suidō Kyōkai, Nippon Suidō-shi, Sōron-hen.

precipitation in Japan, though no smaller than in many other countries, is not appreciably greater than in other densely populated areas (i.e., advanced countries) either. Moreover, in Japan, rice culture consuming large quantities of water had been highly developed already in pre-modern times, and accordingly the drought 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 conflicts with water rights that 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 form swift currents and have high flow rates. Moreover, a large part of the 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 flows 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 of stabilizing the flows 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. Furthermore, the steep grades of rivers reduce the effective capacities of dams, which relatively quickly become filled up with the large quantities of mud and sand flowing into them, and the flow-stabilizing function of dams is thereby adversely affected. 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 subsoil water is abundant, wells have been extensively

Table 4. Annual Precipitations in Different Countries

Precipitation per unit area (mm/year)	Country	Precipitation per capita (m^3/year)
833	USA	38,379
803	UK	3,531
759	France	8,337
805	Fed. Rep. of Germany	3,298
983	Italy	5,479
790	Canada	365,356
1,450	Norway	120,885
556	Spain	11,019
700	Sweden	39,000
664	Turkey	14,523
7,345	Holland	22,996
389	USSR	37,100
836	China	11,100
1,219	India	7,830
1,630	Brazil	162,000
1,800	Japan	6,500
World average 798		World average 28,834

Source: Nippon Kasen Kyōkai [River society of Japan], Kasen Binran 1978 [Handbook of rivers 1978].

Table 5. Regime Coefficients of Major Rivers in the World

Country	River	Point of measurement	Maximum flow rate (m^3/sec)	Minimum flow rate (m^3/sec)	River regime co-efficient
France	Garonne	Toulouse	6,000	36	167
	Seine	Paris	1,652	48	34
UK	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
US	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
	Tenryu	Tenryukyo	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: Shun'ichi Kurosawa, Mizushigen Keikaku.

used by urbanites since ancient times. As rivers are steep in grade, their surface water can be tapped with comparative ease, and many cities did not have to depend on distant water resources. Although the drought water discharges of rivers were exhaustively used for irrigation, the quantity of urban water needs was far smaller than that of water for irrigation in premodern days. There were frequent disputes over irrigation water rights, but urban dwellers had little doubt 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 has had an immense affect on the way waterworks have been developed in modern Japan.

III. WATERWORKS IN PREMODERN JAPAN (WATERWORKS IN EDO)

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

Construction of Kanda Jōsui started almost simultaneously with the establishment of the Tokugawas' headquarters in Edo, and presumably was included in the blueprint for the capital city from the outset of its planning. Its inclusion in the construction programme as one of the basic urban facilities, in spite of the absence of any predecessor ot it in the history of Japanese cities, is believed to have been inspired by foreign missionaries who lived in Japan before her self-imposed period of 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 citywide water networks came to be built in major cities such as London and Paris. This was about the time Western missionaries first came to Japan.

Of course, apart from the presumed influence of foreign missionaries, pre-Tokugawa warlords had always had a vital interest in securing the supply of drinking and fire-fighting water to their castletowns, but they often sought for its sources, mainly wells, within the town limits primarily for defence 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 subterranean water was available, and further because Edo was projected from the outset as the capital city of the national government (although the Tokugawas' takeover of the rule of the nation was somewhat preceded by the construction of the capital) and was expected to develop as a commercial, rather than military, town.

Construction of Kanda Jōsui, whose open conduit extended over 23 kilometres, 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 cores of two well-known parks in urban Tokyo. The small streams flowing out of these ponds have been submerged into urban districts and are now hardly visible. They were much too small to meet the increasing water needs of Edo in later years.

For this reason, Tamagawa Jōsui, tapping the main stream 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 original Kanda Jōsui, constituted the water channelling and distributing network of Edo from then on. Out of the four waterworks built later, Kameari Jōsui derived water from the Furutone River, a tributary of the Tone River system, while Aoyama, Mita, and Senkawa Jōsui were all branched out from Tamagawa Jōsui. Thus the skeleton of Tokyo's water supply system that, tapping mainly the Tama River system and partly the Tone River system, continued to serve the metropolis until recently was already developed by the early Edo period.

Tamagawa Jōsui took in water from the main stream of the Tama River with a dam built at Hamura, conveyed it to Yotsuya Ōkido (then the western limit of urban Edo) through a 43-kilometre open conduit inclined at about one in 500 and further into the city through a stone-built closed conduit; it then distributed it through wooden piping to the residences of major samurai families and innumerable water tanks for common use by townsmen. The conveyance and distribution of water wholly depended on natural flows and not on any pressurizing devices. The waterworks had no curb stops but allowed water to flow freely;

there were no purifying devices either. Although it was thus technically behind the waterworks of European cities in those days, Edo's was the world's biggest water supply system then in terms of the population served. (By the end of the sixteenth century when all six waterworks were complete, 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 Edo water supply network which served that population was certainly the largest such network in the world at that time.)

Underlying the successful construction of such large waterworks in those days were the fairly advanced flood control and surveying techniques that had been accumulated through fief administration by warlords (as revealed by the flood control techniques embodied in Takiō 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. That water channelling and distribution in such large waterworks depended wholly on natural downward flow indicates the advanced level of surveying techniques achieved by that time. Because water-consuming rice culture had stimulated the development of irrigation and draining techniques from ancient times and riverboat 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, and 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 main stream) accomplished about the same time. 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 main stream of the Tama River with the intake dam at Hamura and fed into urban Tokyo, remained the skeleton of the Tokyo water service network for three centuries until modern times, although its channelling facilities were changed. This aspect is particularly impressive in view of the fact that some of the modern waterworks dependent on the Tama River system, built in and after Meiji, took in water at points far downstream but afterwards ceased to do so on account of the contamination of the raw water. 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 fell into disuse in the first half of the eighteenth century partly because the development of wells made subterranean water of fair quality available for consumption.

IV. THE PROCESS OF LEARNING MODERN WATERWORKS TECHNOLOGY

Under the modernization (i.e., 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 the shogunate's rule 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. Railway, port and harbour, lighthouse, forestry conservation, and river improvement projects achieved significant progress throughout the Meiji period by the use of modern technology imported from the West, but waterworks construction was one of the fields that attracted keen interest very early in the era. Underlying this interest were the following factors: (1) the influx of germs from abroad, following the opening of the country to foreign intercourse in the last days of the Tokugawa rule, invited frequent outbreaks of cholera and dysentery in early Meiji years; these diseases took a great number of lives and thereby greatly aroused public concern about sanitation; (2) the contributions that modernized waterworks would make to prevent these water-borne gastrointestinal diseases were made extensively known through the press; (3) Tokyoites were 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 that further enhanced public interest in the modernization of waterworks. For the revision of unequal treaties with the Western powers, which was a top-priority task for the Meiji government, accelerated modernization of Japan was considered a prerequisite, and this 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. Although priority in the modernization process of Japan was afterwards shifted to building up the infra-structure for industry under the slogan "Increase production and develop industry; enrich the nation and strengthen the military," with the improvement of facilities to serve people's everyday needs lagging behind (this trend held on until even after World War II), in those early Meiji years emphasis was still placed on disseminating the Western way of life and redesigning cities in the Western style with a view to facilitating the intended revision of unequal treaties. This circumstance, which is vividly reflected in a subsequent programme of the City Replanning Commission of Tokyo, helps explain 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. Even private interests proposed many plans for waterworks construction, but none of them was realized, on account of financial difficulties, until Kanagawa Prefecture in 1887 built the Yokohama Waterworks, the first modern water supply system in Japan.

Waterworks are hardly suitable for state projects because their beneficiaries are more or less confined to specific geographical areas. The Waterworks Ordinance of 1880 instructed that they should be constructed by municipalities. It seems to be due to this nature of the waterworks projects that their realization was somewhat delayed in spite of the enthusiasm for 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 — its relevance to the treaty revision and sanitation problems thus 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 the national concern 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 and, unlike in Tokyo where waterworks had been built in pre-modern days, a large part of the city's clean-water supply 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-pipe 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 the 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), though other cities were successfully made eligible for state subsidies afterwards.

The modern waterworks of Yokohama and the others that followed it differed from earlier water supply systems in that they used iron pipes, pressurized water, and purifying facilities including sedimentation basins and filter beds. The use of iron pipes may seem merely a matter of difference in material, not relevant to the essentials of waterworks technology, but it brought about major qualitative changes in water distribution and supply systems since it enabled pressurized water to run and be fed to individual households. In terms 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 pressurizing of water, furthermore, greatly contributed to improving the function of waterworks as fire-extinguishing facilities and thereby tremendously

Table 6. Increases in Population Covered by and Supply Quantity of Major Water Service Systems

Year / City	Population currently served (in thousands)					Maximum daily supply (in thousand m^3)				
	1925	1930	1939	1970	1975	1926	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: Doboku Gakkai, Nippon Doboku-shi; Kōsei-shō, Suidō Tōkei.

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 therefore highly flammable wooden buildings and had no pressurized waterworks in pre-modern times, they had developed a unique fire-extinguishing technique known as destructive fire fighting, which did not heavily rely on waterworks. The role of traditional waterworks in Edo as an important 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 is 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 infiltration of filthy water into the lower reaches of the distribution system would make purification meaningless. Distributing pipes, therefore, had to be completely impermeable to contamination from the outside.

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 bacteria removal that, in a crowded city where people 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 traditional ones in this respect.

The Yokohama Waterworks was constructed to the design and under the supervision of British Royal Army engineer H.S. Parmer. In this period, foreign engineers hired by the Ministry of the 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 UK, both playing important parts in the planning and designing of the Tokyo Waterworks. Most of these foreign engineers, who were responsible for the first generation of modern waterworks in Japan, well understood Japanese circumstances, wholeheartedly fulfilled their duties, and enthusiastically trained Japanese engineers. In Parmer's design for the Yokohama Waterworks, the hilltop Yamate Quarter with its largely foreign population was, among the residential districts, excluded from the coverage of the water service since the area was blessed with good well water and therefore, Parmer thought, did not warrant a city water supply in light of the constraints of the budget and available materials. This illustrates the freedom of the Yokohama Waterworks project from flattery 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 — the 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 the Interior, submit his expert opinion on Parmer's design for the Yokohama Waterworks and subsequently 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 period, but stemmed from the particular needs of people's everyday life at the time. The Japanese government had high regard for the economic usefulness of the technical knowledge and experience of foreign engineers and paid them astoundingly generous remunerations, but their place in the bureaucracy was no more than one of mere hired engineers, and they were given no high-level screening or decision-making authority. Their function as technical consultants of high calibre was correctly appreciated, and this made it possible to recruit first-class engineers, recognized as such even in their own countries. These engineers, for 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

Table 7. Number of Government-employed Foreign Experts and Salaries Paid to Them

Year	Number of foreign experts employed	Annual salary per foreign expert employed	Japan's gross national expenditure per capita
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	3,102	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: Kazushi Okawa et al., ed., Chōki Keizai Tōkei - 1. Kokumin Shotoku [Long-term economic statistics - 1. National income]; Kazushi Okawa et al., ed., Chōki Keizai Tōkei - 7. Zaisei Shishutsu [Long-term economic statistics - 7. Public expenditure].

home, were assigned to leading positions in public works projects as technical pioneers. Some of them were concurrently appointed professors at imperial universities or technological institutes and played central roles in the introduction and assimilation of Western technology and in the education of their successors.

Foreign engineers employed by the Ministry of the Interior, including Van Doorn and 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 the academic framework, but this role of theirs was subsequently taken over by indigenous élite 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 the 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 role in the establishment of sanitary engineering in Japan and trained many successors as professor 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 from the late Meiji through Taishō years (approximately 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 (as well as sewerage systems) were made to the responsibility of municipal governments, a handful of sophisticated engineers at universities and central government offices, of whom Nakajima was a typical example, undertook the initial designing of those projects, and local engineers under their guidance then took charge of the waterworks construction, maintenance, and management. This pattern of division of functions was preserved until quite recently. In the development of modern technology, especially industrial technology, design and development functions were in many cases performed by a sector of manufacturing enterprises, with the result that design techniques remained undifferentiated from manufacturing techniques, the former tending to be subordinate to the latter. This was in sharp contrast to the situation 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 nationwide, which came into play during the execution phase of projects planned and designed by advanced techniques imported from the West, this situation of civil engineering technology at the same time undeniably retarded the modernization of the construction industry in Japan.

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 Japan by the mid-Meiji period, and local production of iron pipes for waterworks gradually made progress from the late Meiji through Taishō years, although hasty encouragement of local production without adequate development of technology invited delivery of defective products, which gave rise to an incidence of bribery between the municipal water service of Tokyo and Japan Cast Iron Company (commonly known as the iron pipe scandal). By early in the Taishō period, 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 promulgated in Japan and made important contributions to the subsequent progress of industrialization.

V. CONSTRUCTION AND DEVELOPMENT OF TOKYO WATERWORKS

The downfall of the Tokugawa shogunate invited dispersion of the ruling family's vassals and consequently a decrease in the number of 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. By 1899, Tokyo had approximately doubled its population of a little less than 800,000 early in the Meiji period and had completed its improved waterworks. During this period of rapid growth, 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 the Interior, submitted his opinion on the proposed improvement of waterworks in Tokyo in 1874 and his design for improved waterworks in 1875 at the instruction of the government. Toward the end of 1876, a waterworks improvement committee was established in the Tokyo prefectural government and began systematically to study the improved plan, based on Van Doorn's design. In 1875, the Metropolitan Police Board of Tokyo examined the extent of pollution in Tamagawa Jōsui and Kanda Jōsui. In the year before, the water qualities of the two major supply systems had been

Table 8. Numbers 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	1876	6,307	1877	6,233
1878	6,510	1879	6,631	1880	6,725
1881	6,728	1882	6,734	1883	6,803

Source: Tokyo-to Suidō-kyoku, Tokyo-to Suidō-shi.

checked by the Sanitary Bureau of the Interior Ministry and Tokyo University. The findings of all these surveys indicated that, although the raw waters at their points of intake were highly satisfactory, pollutants entering through the rotten parts of the wooden piping seriously affected their quality to make them mostly unpotable by the time they reached their terminal outlets, and accordingly pointed to the urgent need to improve the waterworks by replacing the wooden pipes with iron ones. In those years, Japan suffered sporadic nationwide outbreaks of cholera in 1877, 1879, 1882, and 1886, apart from an extensive pre-Meiji spread of the disease in 1858. In particular, the outbreak in 1886 took a toll of 110,000 lives in the whole country, and the involvement of 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 programme. In 1887, at the initiative of Eiichi Shibusawa, influential businessmen proposed to operate modern waterworks, based on a blueprint by Parmer 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.

Incidentally, the outbreak of cholera in 1886 drew the attention of Tokyoites to their water source, and 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, declared its intention to place under its rule the three Tama districts, then belonging to

Kanagawa Prefecture. In 1893 it succeeded in doing so. Since the three districts constituted a centre of civil rights movements in those days, suspicions that their transfer to Tokyo Prefecture represented a national government scheme to suppress the movements stirred up a strong campaign to oppose the plan; this was an unexpected by-product of the waterworks problem.

In spite of the early start of planning for the modernization of waterworks in Tokyo, it was not until 1893 that the design approved in 1890 was actually executed, nearly two decades after Van Doorn had submitted his proposal for improvement. The delay was attributable in part to the vast scale of the project by the standards of those days. After all, the waterworks was to serve a population of 1 million, and unavoidably prudence was called for in formulating the plan of execution. But the greater problem was one of fund-raising, for 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, felt they were overtaxed. The costs of waterworks projects are usually levied on their beneficiaries, who can be identified with relative precision, 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 period, while citizens were increasingly aware of the need for modern waterworks on the one hand, there was, on the other hand, serious social unrest aroused by drastic reforms and popular discontent about what was considered too heavy a tax burden. It was therefore difficult to levy a new tax to finance the enormously expensive waterworks project. Meanwhile, the City Replanning Commission of Tokyo was working on a programme to remodel Tokyo into a modern city befitting the capital of a modern unified nation, and this would involve modernization of waterworks as well. Eventually, in 1888, the Tokyo City Replanning Ordinance, which provided for special financing of the redevelopment project among other things, was promulgated as a state law (Imperial Ordinance No. 62 of 1888), and construction of modern waterworks in Tokyo was thus to be undertaken in the framework of this urban revamping programme. This ordinance, too, was formulated only after strong political opposition, 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 Parmer's proposal for a water service company as well as opinions sought from experts in 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 metres (or a per-capita daily supply of 111 litres at the maximum or 75 litres on the average). It would use the facilities of the existing Tamagawa Jōsui for taking in and conveying Tama River water through a new concrete channel to a purifying plant having a sedimentation basin and slow filter. The whole area of the city was divided into 27 higher and lower water supply districts, and the higher districts were directly supplied with pressurized 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 locations 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 designed 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 metres (or 167 litres per head). Until that time, water had been derived from the old Tamagawa Jōsui, but further expansion of water supply could not readily depend on increased intake of the surface water of the river in the dry season because of the limitation of established water rights. Instead, it 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 population and the expansion of the urban area since, on top of the faster-than-expected population growth, the development of additional water resources was retarded by the shortage of funds and materials, the impact of the Great Kantō Earthquake of 1923, and, in wartime, the concentration of financial and material resources in industrial infrastructures at the sacrifice of everyday utilities including waterworks.

In the first stage of water service expansion, 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 late Meiji, but was delayed by the Great Kantō Earthquake and not completed until 1937. In the meantime, towns around Tokyo, which had rapidly developed as a result of the postearthquake migration of population to the suburbs and constituted new urban districts contiguous to the traditional territory of Tokyo, were merged into Tokyo City in 1932; their small waterworks were also integrated with the water service network of the nation's capital. Whereas 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 subterranean water, many households in those satellite cities relied on wells; the proportion of the population needing city water service was accordingly small, because all these new urban districts had too quickly emerged from farming areas for their waterworks to be constructed simultaneously.

In the second phase of the expansion programme, it was planned to intercept the main stream 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 early Shōwa years in preparation for Tokyo's expected growth into a city with a population of 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 the framework of the plan, 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 that had served the modern waterworks system of Tokyo since its founding in the Meiji period was incorporated into the new plant, and the former site of the Yodobashi Plant is now being reutilized as the Shinjuku subcentre of metropolitan Tokyo.

In the meantime, as a stopgap measure, conveying and distributing facilities for water derived from the Edo and Sagami river systems were built in early Shōwa years. The Edo River-based waterworks corresponded to Kameari Jōsui in pre-Meiji days in terms of drainage texture, though using entirely different equipment.

Tokyo's waterworks since the Edo period had primarily tapped the Tamagawa River system. It however, became no longer able to meet by itself the city's water needs that had expanded enormously as a result of the population explosion. In the third phase of the water service expansion programme, therefore, additional supply was sought from the Tone, the biggest river running through the Kantō plain. 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 and competitive needs made it difficult to equitably distribute even the additional volume that could be made available by damming. In view of this situation, the Law for Promotion of Water Resources Development was enacted in 1961 to ensure deliberate adjustment of water demand and supply. Under the new law, the Tone River would be developed as a designated river system. 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 a dam (the Tone Dam) built in Gyoda City, Saitama Prefecture, in the middle reaches of the Tone, fed to the Ara River through the Musashi Channel, allowed to flow along the natural stream of the Ara, again tapped at the Akigase Dam, and further fed 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 contiguous to those of the 23 wards of central Tokyo, were only recently built. For instance in Tachikawa City, which was quickly urbanized since early Shōwa years 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; 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 Great Kantō Earthquake, did not enter service until 1954 and 1959, respectively. (Musashino has within its limits the source of Kanda Jōsui, the earliest of the old Edo waterworks.)

In any of these cities, where shallow wells could readily provide subterranean water of good quality, citizens took no serious interest

Table 9. Coverages of Waterworks in Suburban Cities of Greater Tokyo

	Year of establishment / Year	Hachioji 1928	Tachikawa 1952	Musashino 1954	Mitaka 1959	Ōme 1927	Fuchū 1958	Chōfu 1959	Koganei 1958
Rate of coverage (%)	1950	42				69			
	1953		39						
	1955	35	64	18		60			
	1951	56	90	66	42	81	53	38	43
	1965	98	99	100	100	100	100	100	99

Sources: Nippon Suidō Kyōkai, Nippon Suidō-shi, Kakuron-hen 1; Tokyo-to [Metropolis of Tokyo], Tokyo-to Tōkei Nenkan [Statistical Yearbook of Tokyo].

Notes: 1. The year of establishment is the year in which partial water supply was started in the pertinent city.
2. The rate of coverage equals the population currently supplied with water over the total population of the administrative district.

in building waterworks before sewage from housholds began to noticeably contaminate well water as urbanization progressed. In Tachikawa, a proposal to build its waterworks was triggered by the pollution of underground water by aircraft fuel which had spilled out of a broken pipeline in the airfield of the US Air Force. All the waterworks these municipalities eventually built drew raw water from deep wells and purified it before supplying it to consumers.

VI. SUMMING UP

As I stated at the beginning, Japan has a long tradition of public water service which dates back to the Edo Waterworks, and from the very beginning of her rapid modernization in social structure and institutions, technology, and way of life which followed the Meiji Restoration, both general citizens and government authorities were enthusiastically interested in building modern waterworks. However, although 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 extensive proliferation of such urban facilities, seem to have achieved generally smooth progress, 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, urban life without the benefit of public water supply was a common situation, not only in the satellite cities of Tokyo but also in the rest of the country. In spite of the early enthusiasm of the government, construction of modern waterworks was often ranked low in the priority list of social capital build-up and public engineering works in Japan over the years that followed, and 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 under-developed outskirts, and the inadequacy of water service facilities did not necessarily constitute a substantial impediment to urban development.

As we have seen, underlying the early public enthusiasm for construction of modern waterworks was the general feeling of unrest over sanitary problems aroused by the infiltration from overseas and the wide prevalence of such water-borne diseases 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 water-borne epidemic strikes, there is a great danger that, in a short period of time, its germs may proliferate via water to contaminate the drainage texture and thereby invite its wide prevalence. When bacteriology was still in a primitive stage, the only available way to prevent any epidemic from further spread was sanitary engineering measures based on 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 a sewerage system. In the ancient and medieval ages, West European cities were often attacked by water-borne epidemics, sometimes so heavily that the whole population of the affected city was exterminated. For many centuries since the middle ages these small cities have one after the other improved their water supply and sewerage systems to keep their environments 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 of the latest medical knowledge in this area was quickly conveyed to Japan as well, making it possible to suppress epidemics at their source. This progress in public health and hygiene techniques helped localize any anxiety that might have arisen over suspected contamination of otherwise potable water with pathogenic bacteria thus preventing 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 readily to obtain water by simply turning a cock, which in some cases could be replaced with electric pumps for drawing water from the wells that were then coming more and more into household use. The lapse in public awareness of this aspect of public sanitation even more seriously affected the spread of sewerage systems than that of waterworks. Waterworks could at least make urban life more convenient, but it made no difference in convenience to individual citizens whether they discharged sewage into the sewerage or into the river unless they were concerned about the pollution of the river system. It was not until the 1960s when the Japanese economy began to achieve rapid growth that there re-emerged nationwide concern over the frequent pollution of river systems from the viewpoint of environmental hygiene, the pollution this time coming from heavy-metal compounds discharged from industrial plants.

The early enthusiasm of citizens for construction of waterworks was 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 amendment of unequal treaties. This incidental motive eventually turned out to be one of the factors that contributed to reducing the relative importance of waterworks in the overall programme of public works as Japan's modernization progressed. Even in the Tokyo City Replanning Commission, which was energetically working on its waterworks construction programme, 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 everyday living. Like waterworks and sewerage projects which the Waterworks Ordinance stated were the responsibility of municipalities, many of local governments' tasks directly affected citizens' daily lives, but in the process of Japan's modernization which, under the slogan "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 separated from the mainstream 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 the expansion and improvement of railway service decreased the need for riverboats as a 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. Modern technology imported after the Meiji Restoration was again primarily made up of low-water techniques of Dutch origin. However, the change in circumstances, and the enactment of the River Law in 1896 in that connection, placed high-water projects, intended to isolate rivers from cities with continuous embankments and let floodwater flow into the sea as soon as possible, in the forefront of river engineering. This change in the 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 role that waterworks projects played in river engineering as a whole.

What influenced the development of waterworks even more than these circumstances was the unique way in which the developing pattern of Japanese cities was characterized by the cities' links to farm villages and natural ecosystems. In Japan, traditionally, cities were not artificial environments in which nature was controlled with manmade facilities, but usually developed in a pattern in which they expanded, dependent on the rich natural environments surrounding them, inseparably from rural districts. From the standpoint of city planning, urban and rural areas were continuous. Farmers long continued to use human waste as fertilizer, resulting in a close link between cities and farm villages in this aspect, too. At the same time, waste from urban households was discharged out of cities without polluting the natural environment, including river systems, and returned to natural ecosystems to contribute to the formation and maintenance of farmland. Thus was traditionally established an ingenious order of ecocycles in which cities and villages were integrated.

The function of sewerage consists in isolating urban waste from the natural environment, disposing of it, and returning only treated water into the river system by carrying concentrated waste discharges from the city and properly treating them. Underlying sewerage 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 the natural ecosystem and waste discharges therefrom are dispersed and contained in the natural environment, which treats the waste by its own purifying actions. As Japanese cities expanded preserving much of this rural way of life, the 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, since a large proportion of urban Japan was blessed with underground water of potable quality, dependence on houshold wells did not prove so critically inconvenient. In principle, waterworks and sewerage together constitute an integrated system. In Japan, the inadequacy of sewerage retarded the proliferation of flush toilets and reduced the necessity of waterworks.

When a city's sprawl outpaces the construction of urban facilities, the area of sprawl is likely to be more slummy 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 is now counted among the best residential sections in Greater Tokyo. The urbanization of this area made quick progress after the Great Kantō Earthquake, from late Taishō through early Shōwa years, and the new population in the area mainly consisted of white-collar workers who managed the central controlling functions of Tokyo, which was beginning to expand rapidly at that time, and typically represented the subsequent urban way of life. This seems to indicate that the presence or absence of waterworks led to little, if any, sociological difference in life-style or in other respects. Viewed the other way around, the presence of waterworks had created no particular "urban" way of life by this time.

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

Thus, until a certain stage of urbanization, waterworks were 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; nor did they, unlike railways, help determine 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 dimensions and the densities of activities therein went beyond certain limits, they were well incorporated into and maintained balance with the order of natural cycles. However, the expansion of cities proceeds under a different principle from that of natural balance and, very much 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; moreover, the proliferation of flush toilets and of multistoried buildings made urban life vitally dependent on waterworks. Along with this development, 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 systems, which theoretically should be inseparable from waterworks, still lags far 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 source.

Blessed with supplies of good water, Japanese cities previously consumed water with comparatively little concern. Quantitatively as well, although there were many difficulties in coping with established rights to use the surface water of rivers, the engineers were able to meet enlarged demand by tapping increasingly distance sources and developing seasonal surpluses therein. In the Kantō, Kinki, and northern Kyushu regions, however, since very high proportions of the total water resources are already utilized and few suitable places remain for dam construction, development of new water resources is nearing its limit. Another problem looming on the horizon is that of existing reservoirs being filled up with mud and sand. 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 subterranean water drawn from their own wells. However, as a result of massive pumping of underground water entailed by the postwar economic growth, subsidence occurred in big cities, and to cope with this problem the Industrial Water Law was enacted in 1956, followed by the Industrial Water Service Law in 1958. As a result, the dependence of the water supply on rivers further increased, resulting in an even greater need for the 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 standard of living, the total quantity of 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 the postwar economic growth in Japan. When the national economy was still rapidly growing, the problem of water does not seem to have so

Table 10. Recharge Storage Quantities and Utilization Rates of Water Resources

Region		Water recharge storage in drought year (million m^3/year)	Utilization rate of water resources (%)	
			1975	2000
Hokkaido		49,310	12	19
Tōhoku		72,880	26	36
Kantō		37,650	47	74
Tōkai		40,340	23	37
Hokuriku		20,640	23	33
Kinki		26,160	37	50
Chūgoku	San'in	10,730	16	22
	San'yo	16,920	35	50
	Total	27,650	28	39
Shikoku		19,190	19	29
Kyushu	Northern	12,190	45	72
	Southern	26,690	16	28
	Total	38,880	25	42
Okinawa		1,120	21	55
National total		333,820	26	39

Source: Kokudo-chō, Chōki Mizu Jukyū Keikaku.

Note: The utilization rates of water resources are the ratios of requirements (on an intake basis) in 1975 or projected requirements in 2000 to the recharge storage quantities of water resources in a drought year.

decisively constrained the expansion of cities, but the situation is completely changed now. In the Third National Programme for Integrated Development formulated in 1977, water resources are considered one of the most stringent constraints to regional growth, and in this connection the programme spelled out an idea of development calling for the allocation of population and industry to match the recharge storage of water in each river basin, with this being used as the basic planning unit.

BIBLIOGRAPHY

Doboku Gakkai [Society of Civil Engineers]. Nippon no Doboku Gijutsu — Kindai Doboku Hatten no Nagare [Civil engineering technology of Japan — development process of modern civil engineering]. 1975.

———. Nippon Doboku-shi [A history of civil engineering in Japan]. 1970.

Hirose Korokuro. Toshi Jōsuidō [Urban waterworks]. Gihōdō, 1961.

Koide Hiroshi. Nippon no Kasen [Japanese rivers]. Tōdai Shuppankai, 1970.

Kokudo-chō [National Land Agency]. Chōki Mizu Jukyū Keikaku [A long-term water demand-supply programme]. 1978.

———. Daisanji Zenkoku Sōgō Kaihatsu Keikaku [Third national programme for integrated development]. 1977.

Kurosawa Shun'ichi. Keikakugaku Kōza 9: Mizu Shigen Keikaku [Discourses in sciences of planning 9: water resou-ces planning]. Asakura Shoten, 1972.

Nakazawa Kazuto et al. Doboku Kōgaku Taikei 24: Mizushigen [A compendium of discourses in civil engineering 24: water resources]. Shōkokusha, 1978.

Nippon Suidō Kyōkai [Japan Waterworks Society]. Nippon Suidō-shi, Sōron-hen [A history of waterworks in Japan, a general review]. 1967.

———. Nippon Suidō-shi, Kakuron-hen 1 [Particulars 1]. 1967.

Shibata Tokue. Gendai Toshi-ron [A discourse on contemporary cities]. Tōdai Shuppankai, 1967.

Takahashi Yutaka. Nippon no Mizu Shigen [Water resources of Japan]. Tōdai Shuppankai, 1963.

Takahashi Yutaka, Kanazawa Yoshio, et al. Toshi Mondai Kōza 2: Jūtaku, Tochi, Mizu [Discourses on urban problems 2: housing, land, and water]. Yūhikaku, 1965.

Tokyo Hyakunen-shi Henshū Iinkai [Editing committee for a 100-year history of Tokyo]. Tokyo Hyakunen-shi [A 100-year history of Tokyo]. 1979.

Tokyo-to Suidō-kyoku [Waterworks Bureau of Tokyo]. Tokyo-to Suidō-shi [A history of waterworks in Tokyo]. 1952.

Tomiyama Kazuko. Mizu to Midori to Tsuchi [Water and the green and soil]. Chuō Kōronsha, 1974.