Achieving urban water security in Tokyo

Prepared by - Mukhnaam Kaur Chattha and Zhen Wei

Abstract

Dry spells in Tokyo occur every 10 years; as per a 2014 journal article, Tokyo is the world's largest water stressed city. Since 1970, low rainfall years have become more frequent and observations show an increasing trend between extremely high and low rainfall events, in addition to decreased snowfall and increased early thaw events. Other issues that Tokyo is subject to are earthquakes, floods, and other natural disasters, which cause damage to water supply and sewage networks, thereby disrupting water supply service provisions. The goal of dealing with water shortages is therefore at the core of water resource development in Tokyo. To respond to these challenges the government has expanded the city's water infrastructure, water efficiency, and water conservation measures, in addition to promoting water culture and developing an around the clock emergency water services squad to handle water shortage emergencies. The Japanese government has shown its commitment to integrated water resource management by implementing policies that support coordinated expansion and management of water, land and related resources. Good governance along with access to technical capacity and capital, has led Tokyo to overcome its water problems.

Keywords

Water security; Water Governance; Integrated Water Resources Management (IWRM)

1. Introduction

Water security refers to providing water in the right quantity and quality at the right time for a dependent system. This is a prerequisite for environmental security, human and economic growth (Jacob et al., 2013). Global water resources are not only crucial for personal consumption and the natural environment, but also the agricultural, energy, industrial, and transportation sectors (UN FAO, 2017). As a limited resource, water is affected and restricted by a series of factors such as geophysical conditions, social, and cultural dynamics. Changes in water resources changes the relative wealth of the country, and in many ways, water is one of the most important components that unites society (Jacob et al., 2013). The United Nations defines water security as 'The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability' (UN Water, 2013). At the same time, the UN listed ensuring the availability and sustainable management of water and sanitation for everyone as the sixth target of SDGs (UN, 2015).

In 2014, Tokyo was listed as the largest water stressed city by a research paper that evaluated the world's largest cities based on their water infrastructure using WaterGAP model, where Tokyo's water cycle and consumptive water use of different sectors was modelled (McDonald et al., 2014). Some of the key challenges that Tokyo faces are dry spells which occur once in every decade, climate change causing changes in precipitation, and natural disasters that disrupt water provision. After conducting research it was found that Tokyo has made a range of efforts to secure water supply, which include establishment of: (i) IWRM guidelines at the river basin level, (ii) earthquake resistant water infrastructure, (iii) measures against reducing drought and flooding risks, (iv) water tariff structure that promotes efficient water use, (v) reclaimed wastewater use, and (vi) water conservation measures, ranging from rainwater harvesting to preserving a 23,000 hectare forest for over a century. The purpose of this paper is to study how urban water security is achieved in Tokyo, in addition to providing information to argue that although Tokyo may be water stressed, the government and relevant actors have found methods through implementing hard and soft measures to secure water supply.

2. Background

2.1. Study area

Tokyo is the capital and the largest city in Japan; it is situated in the southern part of the Kanto plain, which lies close to the center of the Japanese archipelago. The total population of Tokyo is 13.63 million people (as of January 1, 2018) which is nearly 10% of the total population of Japan. Tokyo accounts for 0.6% of the total area of Japan and covers a total area of 2,190 km² (as of October 1, 2016) (TMG, 2018).

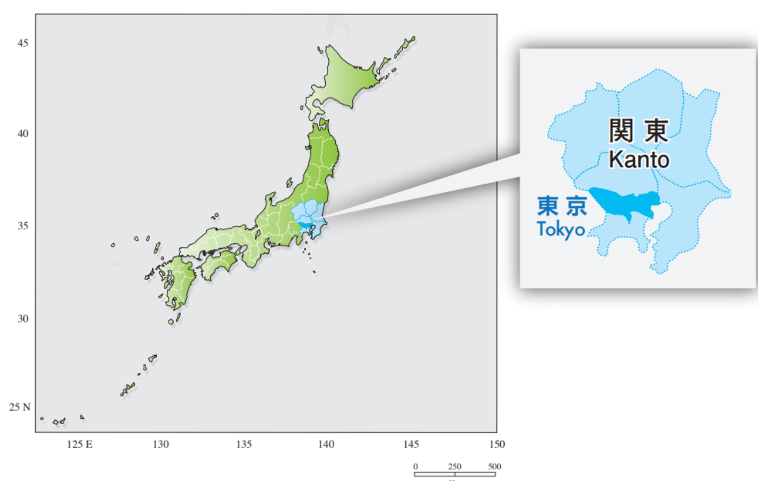


Fig 1. Greater Tokyo Area within Kanto Region (TMG, 2018)

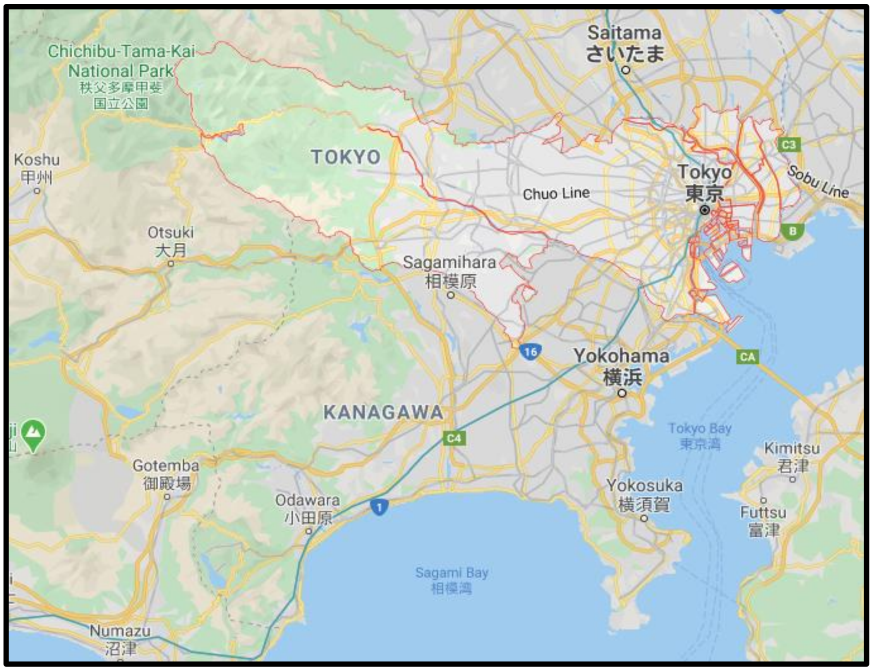


Fig 2. Location of Tokyo city within Greater Tokyo Area (Google Maps, n.d.)

2.2. Water resources

In terms of water resources, Tokyo's 78% water comes from the Tone and Arakawa Rivers, 19% is drawn from the Tamagawa River, and the remaining 3% is from other water resources (TMG, 2018). The region has abundant groundwater resources because of the topsoil in the region being highly permeable. Although, this resource is no longer tapped into because of land subsidence issues as a result of excessive pumping of groundwater for industrial use (Sato et al., 2006).

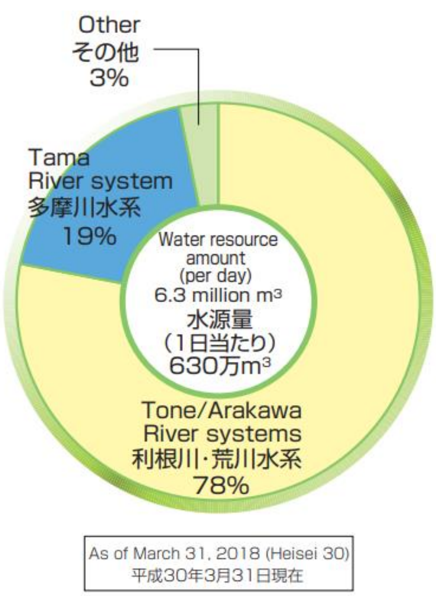


Fig 3. Shows ratio by river system and water resource amount (per day) (TMG, 2018).

2.3. Tokyo's water supply system and water needs

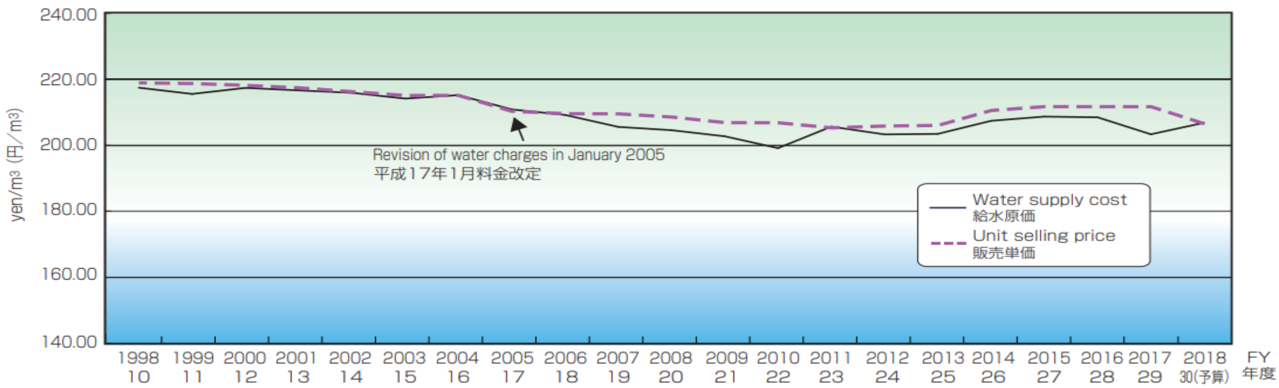
Tokyo's water supply system depends 70% on above-ground water sources such as melted snow, lakes, rivers, and four months of concentrated rainfall (TMG, 2018). A majority of urban water needs for domestic and industrial use are met by drawing water from rivers, dams and other water resource development facilities in the Kanto region (Priscoli & Hiroki, 2016). According to population movement, lifestyle, weather conditions, and social economic conditions, the water demand in the region fluctuates. In Tokyo, per day, the maximum water delivery at its peak is approximately 6 million m^3 (TMG, 2018).

The Bureau of Waterworks supplies water to Tokyo city and as of March 2017, Tokyo's network of distribution pipes was a total length of 27,038 kilometers. To prevent leakages during delivery, the water supply equipment uses stainless steel pipes which supply water from branch points to distribution pipes to meters; this was done because it was found that over 90% of water leakages during delivery were related to the type of water supply equipment used (TMG, 2018). With the prevention of water leakages from pipelines, the water distribution rate in terms of drinking water that reached customers was 92.8% in 2012, from 81.1% in 1975 (Priscoli & Hiroki, 2016). The Tokyo Waterworks Bureau decreased leakage rates by repairs to three percent, which is the lowest in the world (TSS Tokyo Water, n.d.a).

2.4. Water tariff structure in Tokyo

The Tokyo water utility is operated by the Bureau of Waterworks, Tokyo Metropolitan Government (TMG). Water tariffs have been established not only to cover administration costs but also promote efficient water use in Tokyo (Murakuni & Dixon, 2006). As an effort to control user demand, a majority of water agencies adopt tiered water rates or increasing block rates (Priscoli & Hiroki, 2016). Domestic and sewerage water tariffs with increasing-block charges encourage efficient water use. Based on the user's request, the industrial water tariffs are set to an upper limit for the volume of water that can be used. In addition to this industrial and domestic water pricing systems include differential charges for the type of water pipe sizes installed, this provides incentive for efficient use of water, as larger water pipes allow larger volumes of water to be supplied in a second (Murakuni & Dixon, 2006). The aim of the Bureau of Waterworks is to provide customers with the necessary water required for daily use at a cheap rate, and encourage customers to decrease wastage by increasing water charges if customers choose to use more than the necessary amount (Bureau of Waterworks, n.d.a).

Water supply cost and unit selling price



unit : yen/m³ (単位：円)

FY 年度	1998 10	1999 11	2000 12	2001 13	2002 14	2003 15	2004 16	2005 17	2006 18	2007 19	2008 20	2009 21	2010 22	2011 23	2012 24	2013 25	2014 26	2015 27	2016 28	2017 29	2018 30(予算)
Water supply cost 給水原価	218.67	216.62	218.61	217.80	217.00	215.10	216.24	211.54	209.74	205.81	204.72	202.72	198.83	205.89	203.34	203.51	207.80	209.19	208.95	203.38	207.16
Unit selling price 販売単価	218.72	218.52	217.97	217.24	216.09	214.95	214.97	210.23	209.53	209.46	208.51	206.85	206.80	205.30	205.83	206.02	210.48	211.61	211.61	211.59	206.50

Fig 4. Shows transition of water supply cost and unit selling price over the years (TMG, 2018).

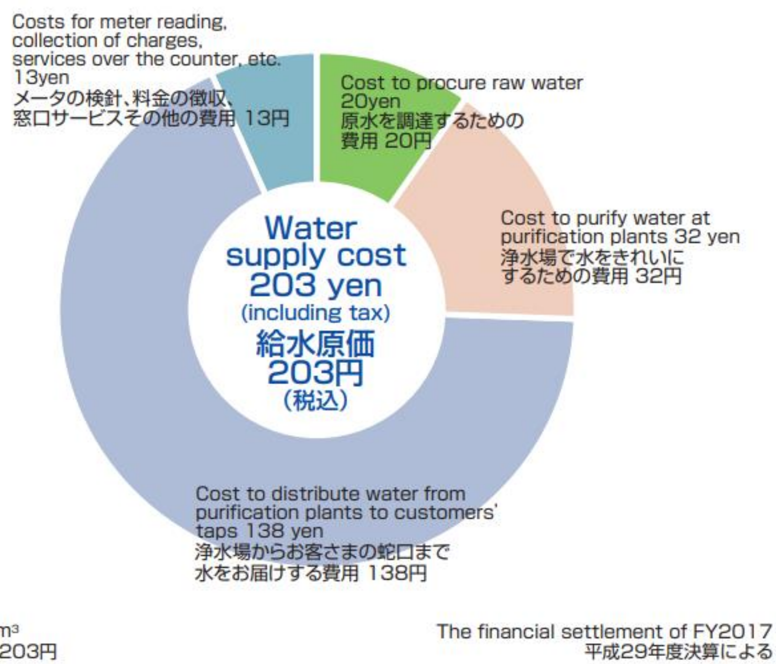


Fig 5. Shows the breakdown of water supply cost (TMG, 2018).

2.5. Water governance and management

2.5.1. Development of water resources

The Japanese government prepared a "National Comprehensive Water Resources Plan" ("Water Plan No. 21") in June 1999, which clarified the primary direction of water resources development, protection, and utilization. The plan set goals to achieve three objectives between the years 2010 and 2015: (i) establish a sustainable water system, (ii) protect and improve the water environment, and (iii) revive water-related culture. As per the Water Plan, a basic outline for water resources development was developed in major river basins across the country. The goal was to reach approximately 258 m^3/sec of water in the Yinchuan River and Arakawa River, and in 2001, 64% of this goal was achieved (MLIT, 2001). However, it was found that more resources were needed to meet the anticipated water demand, and dams were used as the main tool for developing water resources, as rivers and groundwater alone could not meet demand. The construction of dams allowed to meet demand for domestic water, industrial and agricultural water use, in addition to providing other uses such as power generation, and flood control. In April 2001, after the improvement of water resources development facilities, the total water storage reached approximately 2.5 billion m^3 (Takesada, 2009).

2.5.2. Compensation measures for upstream residents

Before the construction of water resources development facilities such as dams, it was essential for the government to reach an agreement with the residents who were residing where the development had to take place. Measures such as the government resettling the residents affected by providing a living infrastructure in upstream reservoir regions were taken (Kaigi, 2009). In addition to these measures a 'Law Concerning Special Measures for Reservoir Areas' was created (MLIT, 2001). The setting of this compensation measure helped solve some obstacles that construction of dams can have on community areas where development is planned to take place. To meet the water demand of Tokyo through the construction of dams, this is an example of how the government effectively worked together with residents to reach an agreement.

2.5.3. Using water effectively

Effective use of water resources is not about rebuilding large-scale facilities to alleviate the gap between supply and demand. It is also essential to reduce the impact of drought. One of the examples established in the Greater Tokyo area is effective water use, such as treated sewage, recycled industrial wastewater, rainwater, and other types of non-standard water resources. Although the water quality is low, this water can be used for toilet flushing, refrigeration, and sprinkling purposes (MLIT, 2001). The Ministry of Construction (MOC) advocates actions such as building water-saving houses (MOC, 2000). The effective use of water resources and the reuse of wastewater recycling have reduced the consumption of water resources, these efforts showcase how government can play a role in implementing effective use of water governance.

Table 1. Stakeholders involved to ensure water security

RELEVANT ACTORS (TMG, 2018)	RESPONSIBILITIES
Ministry of Internal Affairs and Communications	• Participated in the preparation of overseas development strategies for the water industry, led by the Ministry of Economy, Trade and Industry (including the Ministry of Water Resources). The strategies are based on the "The Export Strategy for Infrastructure Systems". Targets were revised in 2018, and aim to obtain orders for infrastructure projects with a total value of 30 trillion yen in 2020 (METI, 2018).
Kanto Bureau of Telecommunications	• Community news broadcasting, • Disaster countermeasure support (SOUMU, n.d.).
Ministry of Finance	• Maintain and manage the nation's financial affairs (Cabinet of Japan, n.d.).
Kanto Regional Development Bureau (MLIT)	• In the event of a disaster, the Kanto Regional Development Bureau is responsible for the early securing of emergency transportation roads and the early restoration of river embankments, port facilities, etc. (KTR, n.d.)
Ministry of Health, Labor and Welfare	• Water supply for domestic use (Water supply law, Law to promote implementation of programs which enable source water quality protection for public water supply) (MLIT, 2008).
Kanto Bureau of Economy, Trade and Industry (METI)	• Water supply for industrial use and hydroelectric power generation (Industrial Water Law, Industrial Water Supply Business, etc.) (MLIT, 2008).
Ministry of Land, Infrastructure, Transport and Tourism (MLIT)	• *Water Resources Department* - The department is responsible for overall coordination of adjusting measures for water supply and demand planning, and reservoir area development (Water Resources Development Promotion Law, Japan Water Agency Law, Law concerning special measures for Reservoir Areas, etc.). • *Sewerage & Water Waste Mgmt. Department* - (Sewerage Law, etc.) • *River Bureau* - Flood control, river water utilization, and dam construction (River Law, Specified Multipurpose Dam Law, etc.) (MLIT, 2008).
Ministry of the Environment	• Conservation of water quality and environmental preservation (Water Pollution Control Law, Water quality Laws relating to conservation of headwaters for preserving quality of drinking water supply, etc.) (MLIT, 2008).
Japan Water Agency (JWA)	• Constructing dams and facilities • Flood control • Maintaining and improving normal functions of the river water, for example conserving river environment or securing vested water. • Securing water for domestic, industrial and agricultural use (APFM, n.d.).
Japan Water Works Association (JWWA)	• Water Utility Management Advisory • Technical Research of water supply management, technologies and water quality. • Publish water supply related books on management and technical subjects. • Training: JWWA provides training to improve skills of employees working in water supply utilities. • Inspection Service: Based on objective inspection criteria, the organization conducts performance testing and product inspections of water supply equipment and materials. • GLP Accreditation Service - Water Supply Service: In 2009, JWWA also developed “Guidelines for Tap Water Quality Testing Good Laboratory Practice” (GLP). (JWWA, n.d.)
Japan Industrial Water Association	• Investigation and research on industrial water • Proposal and reporting on industrial water to the Parliament and the Government • Conducting visits and inspection, and holding workshops, lectures, classes, meetings, and exhibitions • Preparation and distribution of reference books and materials such as journals • Research and investigation of the standards of industrial waterworks • Activities necessary to achieve the purpose of the association (JST, 2009)
Public Utility Services Center Co., Ltd.	• Customer service at stations • Meter reading and billing - Providing computerized calculation of water charges • Collecting water charges (PUC, n.d.)
TSS Tokyo Water Co., Ltd.	• Design, construction, operation and maintenance of waterworks & related facilities • Design,construction and supervision of water supply facilities • Operation and maintenance of water supply facilities Water quality assessment • Waterworks consultation and training • Management and sale of water supply equipment and materials • Research and development on waterworks • Worker dispatching undertaking (TSS Tokyo Water, n.d.b).

Table 2. Major laws and regulations (TMG, 2018)

NAME OF LAW OR REGULATION	OUTLINE OF LAW/ REGULATION/ RELATIONSHIP WITH OPERATIONS OF THE BUREAU
Waterworks Law	'The Waterworks Law' sets the basis for waterwork operations and states water quality standards, conditions for approval of operations, installation and management standards of waterworks, organized improvement for facilities, etc.
The Industrial Water Supply Business Law	'The Industrial Water Supply Business Law' specifies the principles for industrial waterworks operations and identifies notification of operations,obligation of water supply, standards of facilities, etc.
The Local Public Enterprise Law	'The Local Public Enterprise Law' stipulates fundamentals of operation management and specifies the management organization, finance, handling of the status of enterprise personnel, etc.
The Local Autonomy Law	'The Local Autonomy Law' lays out the installation, management and usage charges, etc., of waterworks facilities for public service.
River Law	The 'River Law' defines parameters for occupancy of river water as a water source, approval for new construction, etc., of structures, management of dams, etc.
Basic Environment Law	The 'Basic Environment Law' sets water quality standards.
Water Pollution Control Law	To prevent pollution of public waters, the 'Water Pollution Control Law' defines the regulations fo the discharged water from business establishments and factories.
Water Supply Ordinance of the TMG	The 'Water Supply Ordinance of the TMG' stipulates water charges for Tokyo, allocation conditions of the cost of water supply equipment works, and the conditions required to maintain an appropriate water supply.
Industrial Waterworks Ordinance of the TMG	'Industrial Waterworks Ordinance of the TMG' stipulates the area of industrial waterworks in Tokyo, water charges for Tokyo, allocation conditions of the cost of water supply equipment works, and the conditions required to maintain an appropriate water supply.

3. Key issues and challenges

3.1. Climate change

Over the past 100 years, the average annual surface air temperature in Japan has increased by approximately 1°C. Since 1970, in terms of precipitation low rainfall years have become more frequent. The years (1973, 1978, 1984, 1994, and 1996) when water shortages caused damage, the precipitation amounts received were below average. Observations made also found an increasing trend between extremely high and low rainfall events. In addition to decreased precipitation and recurrent low rainfall years due to climate change, trends also showed decreased snowfall and increased early thaw events (MLIT, 2008).

3.2. Dry spells

As per the Bureau of Waterworks, water shortages in Tokyo occur once in every decade (Bureau of Waterworks, n.d.b). Most recently in 2016, several river basins faced a shortage of reservoir water, which led to water users having to restrict their water intake. One of such river basins was the Tone River basin, whereby the cause of the water shortage was an amalgamation of a lack of winter snowfall and rainfall in May. In the upper Tone River basin, Ozenuma observation station recorded the lowest maximum snow depth in 62-years of 172 cm in 2015-2016, which is an amount that is only 60% of the annual average. The snowpack at the observation station melted one month earlier than the average at the end of April. In addition to this, the upper Tone River basin reported only 48% of the average monthly rainfall for the month of May in 2016. The deficit of river flow was filled by eight reservoirs in the area (see Figure 6.) from early May to early June. The first drought coordination council was organized on June 14 by the Kanto Regional Development Bureau, when the total volume of the eight reservoirs reached 45% of the annual average. A 10% intake cut was maintained from June 16 to August 24 by domestic, agricultural, and industrial water users, until the restriction was removed when Typhoon No. 9 brought adequate rainfall to the area (Priscoli & Hiroki, 2016).

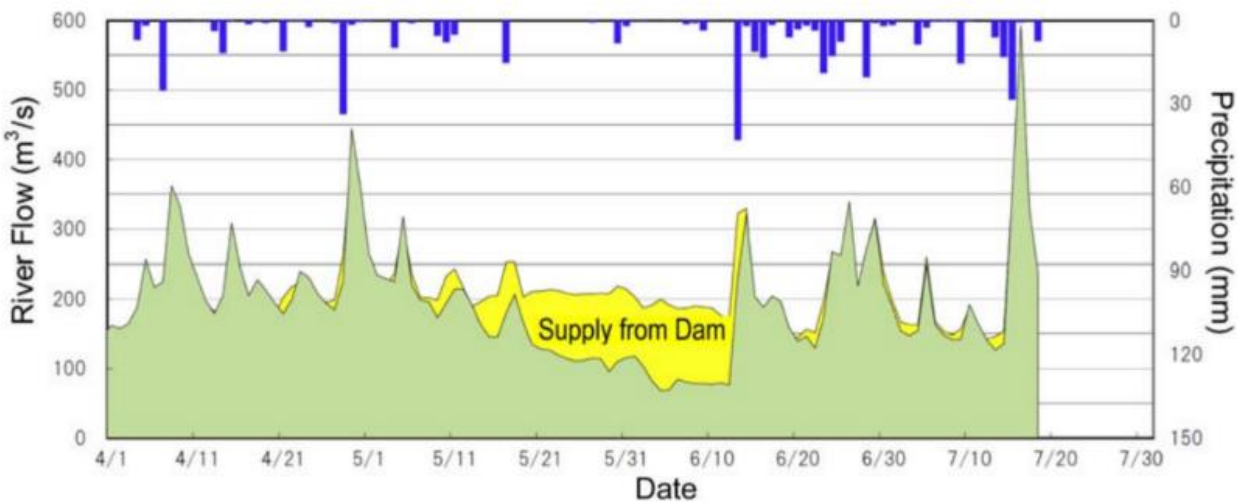


Fig 6. Tone river flow and supply from dam reservoir in 2016 (Priscoli & Hiroki, 2016)

3.3. Natural disasters

Tokyo is subject to earthquakes, floods, (IWA, 2019) and weather-related natural disasters such as typhoons, heavy rains, windstorms, and snow (MOFA, n.d.). These events cause damage to water supply and sewage networks, thereby disrupting water supply service provisions (IWA, 2018). For example, after the 2011 Japan Earthquake it was reported that millions of Japanese residents faced the threat of no water resources after the earthquake. This is because the restoration of water supply infrastructure usually takes several weeks (Walton, 2011). A 2010 research survey found that TMG has polished its management skills in the comprehensive use of water resources, through unified control of water levels and water quality, efficient water usage, reuse of sewage-treated water and protection of the ecosystem (Yoichi & Asahi, 2010).

3.4. Pollution

Around 120 rivers are flowing through Tokyo, including the Tama and Sumida rivers. Although the water quality of these rivers declined significantly during the period of rapid economic growth, there has been remarkable improvement since the 1970s due to the control of pollutants from sources like factories and developments to sewage systems. Compared with the early 1970s, the water quality of Tokyo Bay has also developed (Bureau of Environment, 2018). However, the TMG still has some problems to overcome, such as algal bloom incidents (Anderson et al., 2019).

3.5. Water privatization

Under Japan's increasingly aging population, the revised "Water Supply Act" aims to strengthen the quality of municipal water supply services and to renovate to prevent the aging of water supply facilities. But some critics worry that the law paves the way for local governments to sell rights to manage water services for up to 20 years, which would lead to privatization, whereby the government would not be able to make a positive and timely reaction. According to the TMG, one-third of the municipalities that manage water supply services are not able to pay water bills to cover operating costs, and the situation is expected to worsen as the country's population declines (Tomohiro, 2018).

4. Efforts made to achieve water security

4.1. Coordinated drought risk management

Once every three years restrictions are applied on water intake in the downstream of the Tone River basin (Lossouarn et al., 2016). There is a tight supply of water in the capital area and in the past 10 years water restrictions have been imposed three times to ensure continuity of water resources and stabilize water use in the Tone River basin. The restrictions help in increasing water supply of municipal and industrial water to the Tokyo area (Tournier et al., 2019).

Through real time telemeter systems, river runoff and water storage volume of dam reservoirs are continually monitored by river and dam administrators. A drought coordination council is initiated in an event of decrease in river runoff or reservoir levels, and when the entitled water use is forecasted to be impacted. The council comprises of the river and dam administrators (e.g. Japan Water Agency, the local government, Ministry of Land, Infrastructure, Transport, and Tourism (MLIT), etc.), in addition to water users (e.g. irrigation organizations, domestic and industrial water supply agencies, hydraulic power companies, etc.). Drought coordination meetings are regularly organized to update entities on river and reservoir data, drought prediction based on data, and the associated impacts of a drought event on water users. In times when drought conditions worsen, council members come to an agreement on step-by-step water withdrawal restrictions, where members monitor drought impact and persuade end users and citizens to conserve water (Priscoli & Hiroki, 2016).

Article 53 of the River Law specifies all water right holders to coordinate amongst each other during drought conditions, and also highlights the responsibility of the river administrator to provide the necessary information for proper coordination. In cases where an agreement cannot be reached it is the river administrator’s duty to mediate negotiations. The purpose of water use (drinking water, agriculture, industry) does not affect who is given priority to access water, but it depends on the order the rights were granted. Generally, water rights are built on lowest river flow in ten years, in instances whereby river flow decreases below this threshold the entitled water amount may not be withdrawn. Therefore, the right to access river water depends on river flow, and water users cannot claim water rights against river administrators (Priscoli & Hiroki, 2016).

During severe drought situations, the government arranges a drought response meeting with 11 water relevant ministries and agencies, with the goal is to respond to the drought event with suitable measures. Generally, each water-related ministry and prefectural government is held accountable to have its drought response headquarters. In the past to respond to droughts a range of measures have been applied, which include: (i) converting reservoir water allocated for hydraulic power to water supply, (ii) temporarily using water from private wells, (iii) delivering drinking water by water tanks, (iv) conducting a public campaign on water saving, and (v) putting a hold on water that is used for public and school swimming pools (Priscoli & Hiroki, 2016).

4.2. Stakeholder participation in water resources management

In 1997, the River Law was amended to plan for flood control, water use, and environmental conservation for formulating a river improvement plan for all rivers in Japan. The law required public participation to be a part of the planning process. Another example is when the Tama River plan was established by conducting roundtables which actively involved local residents, municipalities, industry, academic experts, and administrators. A total of 26,600 people from the basin were involved in river basin seminars, river inspection tours, and civil action, organized by the residents and administrations. Plan development was completed within two years, which was much quicker than anticipated because of effective stakeholder participation from the beginning of the planning stage (MLIT, n.d.a).

4.3. Evidence of commitment to IWRM in Tokyo

4.3.1. IWRM guidelines at River Basin Level: A spiral approach

Japan's integrated water resource management (IWRM) encourages sustainable water use and water cycle governance by implementing relevant policies and frameworks that involve appropriate sectors and stakeholders (MLIT, n.d.a). The IWRM guidelines set at the River Basin Level have been developed by UNESCO/IHP in partnership with the Network of Asian River Basin Organizations (NARBO), to contribute to the World Water Assessment Programme (WWAP) (Nakajo, 2010).

Tama River

From the 1960's the Tama River basin was being rapidly urbanized, whereby environmental conservation and the use of riparian buffers by communities became major issues. In the beginning of the 1970's the civil society became concerned with the disappearing of natural areas by the Tama River. The public opposed the development of ecologically rich riparian zones into sports areas. In support of river preservation many public activities began to spring up. This made the government to establish the 1980 Tama River Environmental Management Plan. This plan was the first of its kind in Japan, developed through direct dialogue with local residents. In 1987, to promote awareness on measures that improve the Tama River environment, the Tama River Basin Council held a 'Tama River Week' for residents and administrative agencies. To further continuous knowledge exchange to build a collaborative framework on Tama River improvement, in 1988 a Tama River Basin Roundtable involving residents, river managers, academic experts, basin municipalities, and other relevant stakeholders was held. This was done to build trust amongst stakeholders and aid in consensus-building to establish a 'good river/good city' management approach. In 2001, to further river improvement the 'Tama River Improvement Plan' for the next 30 years was developed by collaborating with all relevant stakeholders. In terms of NGO and civil society volunteer activities, there are at least 200 existing organizations that provide networks for a range of civil groups to exchange knowledge (UNESCO, 2009).

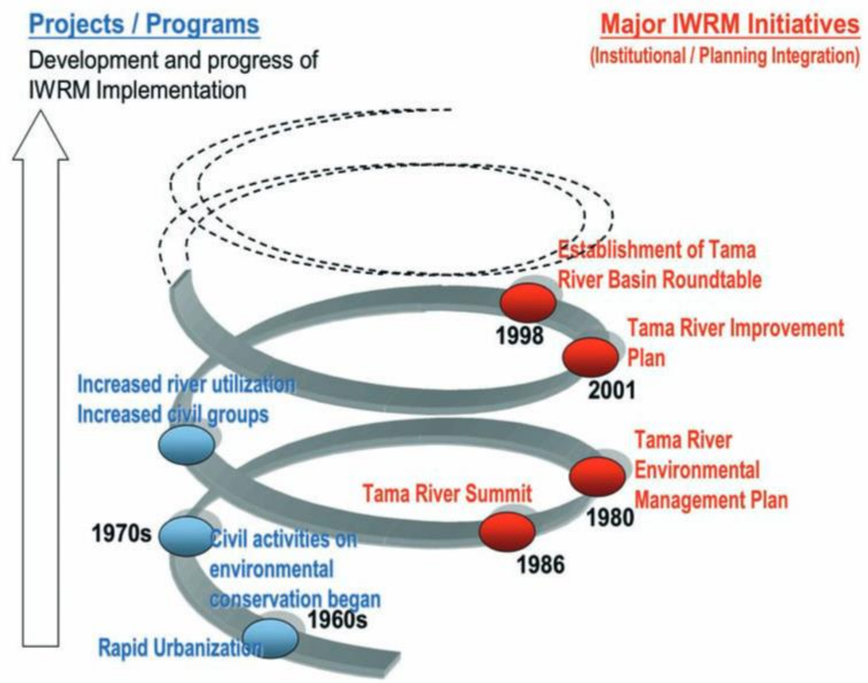


Fig 7. The IWRM Spiral of the Tama River basin (UNESCO, 2009)

Tone River

Since 1958, restrictions on water supply have been common in Tokyo, particularly during summer months, when water demand of local residents is met by transporting water by trucks carrying water tanks. Even though Ogochi Dam completed construction in 1957, the dam could not meet the demand of the Tokyo region. Impacts were further compounded by land subsidence as a result of excess groundwater pumping for industrial use, and riverbed degradation of Tone River which caused water levels to sink. In this situation the Tokyo metropolitan government (TMG) sought a new water source. In 1958, it was declared by the government that water in the upstream dams would be conveyed via a pipeline upstream of the river area to an existing purification plant. In 1961, the Water Resources Development Promotion Law and the Water Resources Public Corporation Law were both developed, in addition to an implementation body established by the government to develop an integrated plan for water use and flood control for the river basin. With the Water Resources Development Promotion Law in place, for the first time the Tone River was designated as a river system on the basis of the law, it was decided that intake facilities would be unified (barrage construction) and a 14km long canal would be developed to connect Tone and Ara River. In 1963, the government also announced a plan to develop Tone River canal. The construction of this canal was completed in 1968; this measure along with the intake unification barrage helped stabilize not only water intake, but also water supply (UNESCO, 2009).

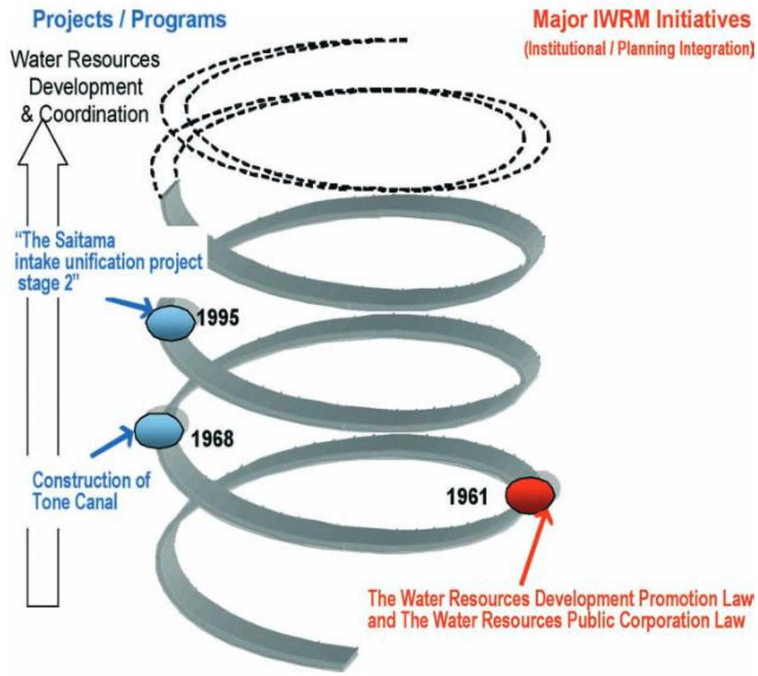


Fig 8. The IWRM Spiral of the Tone River basin (UNESCO, 2009)

4.3.2. Water conservation

Water Conservation Forest

The water conservation forest located upstream in the Tama River has been managed by the Bureau of Waterworks, TMG for over a century. It is the largest forest managed by a water-supply corporation in Japan. The total area covered by the water conservation forest is 23,000 hectares, stretching nearly 20 kilometers north and south, and 31 kilometers east and west. The rain that falls in the forest infiltrates into the spongy soil and the runoff flows slowly towards the river, this aids in stabilizing the volume of water in the river, preventing extreme events like droughts or floods. Due to this function of the forest, it is popularly known as the "green dam". Another purpose that is served by the forest is that it acts as a natural water filtering plant, in addition to preventing soil from flowing into the river (Bureau of Waterworks, n.d.c.).

The Ogouchi Dam developed on the mainstream of the Tama River maintains low rates of sediments because of the maintenance of the conservation forest. Generally, with the ongoing usage of a dam significant sediment is built up because of driftwood and soil flowing into the river from the forest. However, because of proper maintenance of the forest by the Bureau, this issue has been avoided for over 50 years, and the amount of sediment in proportion to the volume of water has been maintained at a low rate at 3.2 percent (Bureau of Waterworks, n.d.c.).

Rainwater harvesting

To expand water storage capacity, rooftops in Tokyo have been transformed to rainwater catchments (Furumai, 2008), this has been done to preserve water resources (Furumai, 2016). As of March 2002, within the Tokyo Metropolitan Area there were at least 850 rainwater harvesting facilities of which 284 were private buildings and 566 were public buildings. Some large-scale rainwater storage facilities in Tokyo are shown in Table 3. (Furumai, 2008). An accurate number on how many of these 850 rain collection systems are in Tokyo city specifically, and whether the number of facilities have increased in the Tokyo Metropolitan Area is missing.

Table 3. Some large-scale rainwater storage facilities in Tokyo (Furumai, 2008).

PLACE (YEAR)	EFFECTIVE CAPACITY (m3)	PURPOSES
Kokugikan (1985)	750	Toilet flushing, cooling water
Sumida-ward office (1988)	1000	Toilet flushing
Tokyo dome (1988)	1000	Toilet flushing

There has been much interest in Tokyo and other regions in Japan in the use of household rainwater storage systems so that in times of emergencies, these reserved water sources can be used for firefighting or as emergency water supplies during disaster events. In the Mukojima district of Tokyo, collected rainwater from rooftops is already being used for garden watering, firefighting and as drinking water during emergencies. Although rainwater harvesting is being utilized in Tokyo as a water preservation strategy, it has a greater potential to flourish and play a major role in acting as a water supply source, flood preservation measure, and as a disaster mitigation strategy (CSE, n.d.).

4.3.3. Water efficiency - Reclaimed wastewater use

Tokyo Metropolitan Government (TMG) manages the “wastewater reuse” business to use water resources effectively. In this business, wastewater from sewers is highly treated and then used in various urban non-potable water uses. Since 1984, this business includes a regional recycling system of recyclable wastewater for toilet flushing. As of 2008, an average of 8400 m^3/day of recycled water had been supplied to 129 facilities, and the scale is still expanding. Another use of reclaimed sewer wastewater is that it is discharged into urban rivers, which have low flow rates as a result of climate change and urbanization. Besides this use secondary wastewater or highly treated wastewater can also be used for washing, firefighting, road spraying, entertainment in the park and so on (Furumai, 2008).

4.4. Reinforcement of earthquake-resistance of waterworks system

In March 2011, a seismic intensity of “upper 5” was recorded in Tokyo, as a result of the Great East Japan Earthquake so-called “epicentral earthquake”. According to the Tokyo Government Disaster Prevention Council’s projection, once occurred epicentral earthquakes in some regions can cause seismic intensity of 7 at maximum and an average of “upper 6” in a large number of regions. As a result, Tokyo Waterworks has enhanced their backup functions and established a water supply system that is earthquake-resistant so that in case of occurrence of serious earthquakes, water supply is secured. Some of the measures under backup functions include: (i) duplexing water conveyance facilities, and (ii) duplexing and reinforcement of water transmission networks. Whereas, under earthquake-resistance of waterworks facilities major measures include: (i) reinforcement of earthquake-resistance of purification plants and water supply (distribution) stations, and (ii) set up of independent electricity (reinforcement of non-utility power generation facilities) (TMG, 2018).

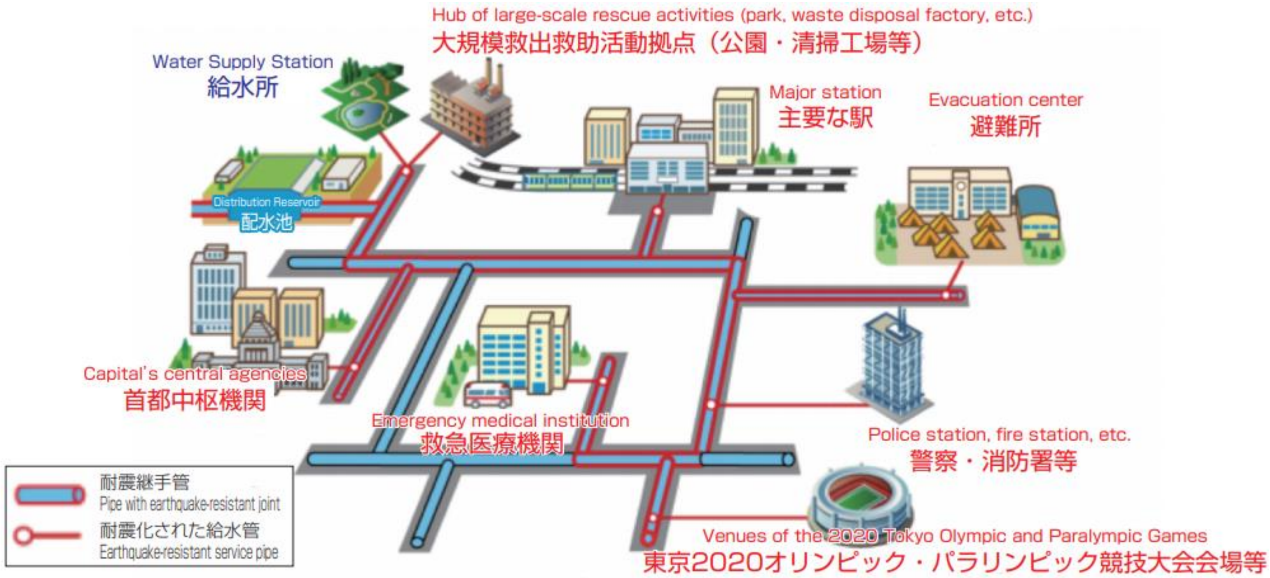


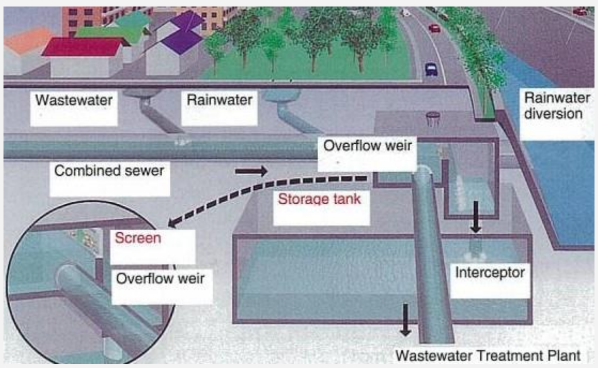
Fig 9. Shows pipe jointing done with earthquake-resistant joints in water supply pipes connected to major facilities (TMG, 2018).

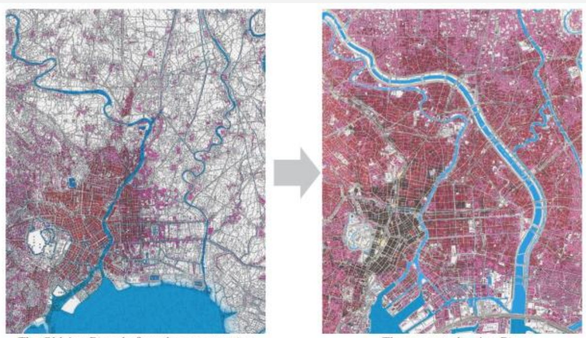
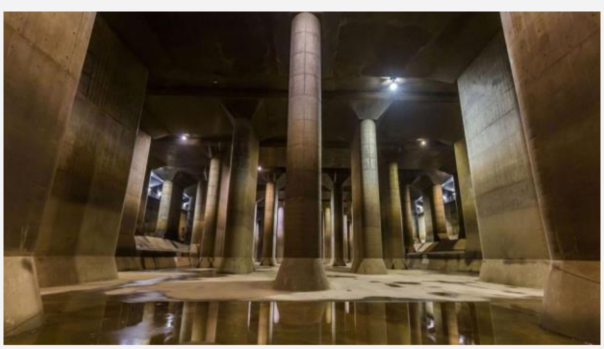
4.5. Emergency services

Emergency water supply stations have been set up in case of water shortages or other types of accidents that can occur during earthquakes. Over 200 water supply bases (water purification plants, water supply stations, and emergency water supply tanks) have been established, so that there is one water supply base within a radius of two kilometers from any place. Water supply tanks connected to distribution pipes, constantly store 1,500 or 100 m³ of freshwater which comes from pumped water recycling systems. In order to complement emergency water supply points temporary taps have been installed by fire hydrants which are near evacuation sites. This is done as part of restorative work in case there is a necessity in water stoppage areas. Additionally, an all year round, around the clock emergency water services squad has also been established to handle water shortage emergencies (TMG, 2018).

4.6. Flood risk reduction

Table 4. Shows some measures that have been established to reduce flood risk in Tokyo.

<table>
<tr><th>MEASURE</th><th>FIGURE</th><th>FUNCTION</th></tr>
<tr><td>Advanced Flood Control measurement systems</td><td></td><td>Advanced flood control measurement systems are used in the urban area to secure services (Lossouarn et al., 2016).</td></tr>
<tr><td>Wastewater system update</td><td>
</td><td>At present, the wastewater system is also being updated to cope with localized heavy rains which exceed 50mm/hr (Lossouarn et al., 2016).</td></tr>
<tr><td>Rainwater storage and penetration facilities</td><td>
</td><td>Rainwater storage and penetration facilities have been set up in playgrounds and other areas such as residential areas and roads which allow penetration and storage of rainwater (MOC, 2018).</td></tr>
</table>

Underground Regulating Reservoir	 LOOP RD NO. 7 UNDERGROUND REGULATING RESERVOIR	Loop Road No. 7 Underground Regulating Reservoir is a huge facility built under the Kandagawa area in Tokyo and includes a 4.5 km underground tunnel with an inner diameter of 12.5m. The first phase of the reservoir construction was completed in 2008 and lasted 10 years. The second stage of construction to expand the reservoir capacity is still in progress and it should take nearly 10 years to complete. The reservoir can store approximately 540,000 m^3 of flood water from the three water intake facilities of the Kanda River, Zenpukuji River, and Miaofa Temple River (Plaza Homes Ltd., 2019).
Ara River Floodway	 The Old Ara River before the construction of the floodway (The present-day Sumida River) The present-day Ara River	The Ara River floodway was made to increase the flood discharge capacity by adding a new river channel to reduce the risk of flooding. A flood channel, 22 kilometers long and 500 meters wide was constructed for the Ara River that flows through Tokyo after the flood in 1910 (MOC, 2018).
Preventative Measure - Metropolitan Area Outer Discharge Channel Facility		The facility connects 5 major waterways and rivers such as the Nakagawa, Kuramatsu, and Ootoshi-Furutone Rivers, and drains the water from them directly into the Edogawa River to prevent flood damage in Tokyo city and its surrounding areas. The 6.3km long facility consists of 5 silo-shaped water storage spaces–of varying sizes–each connected by tunnels that were constructed approx.50m underground (Plaza Homes Ltd., 2019).

4.7. Pollution control

According to the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), an effective method for dealing with water pollution is to establish water quality standards, regulate the treatment of industrial wastewater, construct sewage treatment systems, dredge contaminated sediments, and formulation of sewage discharge standards (MLIT, n.d.b). In two successful cases in Tokyo, it was found that with the progress of sewage construction, the water quality of the Tama River improved, creating a good water environment for Tokyo residents. The Sumida River also became a representative landscape of Tokyo through sewage regulations, sewage construction, dredging of contaminated sediments and water-turned purification (Kitamura, 2012). With the improvement in river water, clean water supplies are now widely available, and deaths from infectious diseases caused by contaminated water sources have declined significantly (MLIT, n.d.b).

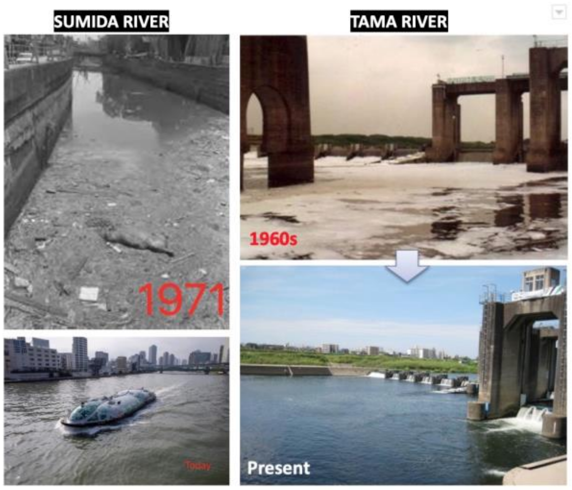


Fig 10. Shows the result of pollution control on Sumida River and Tama River (Kitamura, 2012)

4.8. Privatizing some water supplies as a means to ensuring sufficient funds

In future, Tokyo could face the monetary burden of its aging water infrastructure. Therefore, to deal with this problem, some water supply projects have already been entrusted to be operated and managed by private entities. According to the Tokyo water supply system data, Tokyo's water supply system coverage is almost 100%, on the other hand sewage coverage was more than 70% as of 2007. In recent years, however, the water supply system is approaching its useful life as water facilities begin to deteriorate. The need for renovations and renewals is expected to increase significantly. The Tokyo government estimated that if the amount of investment continues to decline year by year, the demand for upgrading facilities will exceed the amount of investment set by the government of Japan by 2020 (the government of Japan has strict limits and requirements on fiscal expenditure) (METI, 2008).

This led the government to focus on programs to revise investment in water facilities to make better use of private sector funds. For example, the 2002 amendment to the Water Supply Act indicated that the technical operation of some water supply systems was entrusted to third parties (including private entities). This was done so that enough funding is available to renovate water facilities. In projects assigned to third parties, only a small percentage of the projects are delegated to private entities. Therefore, it is still not possible for private water service providers to take control of the entire value chain in the future to replace municipalities (METI, 2008).

5. Discussion

A paper in 2010, mentioned water utilities in Tokyo as an example of good water governance (Tortajada, 2010). It is evident from the paper that different actors have been working for several years to achieve water security in Tokyo by building resilient water supplies, expanding sewer system coverage, to implementing water efficient, and water conservation measures. Efficient water governance and management, whereby the Japanese government has implemented policies and regulations that safeguard water quality and quantity, in addition to involving multiple local public and private stakeholders (Table 1.) who help implement regulations at the local level, as well as bring specialized knowledge to solve water-related problems, are some ways in which governance has paved the way to achieving water security in Tokyo. Even in terms of management and budgetary practices as mentioned in section 2.4. relating to water tariff structures, water utilities acknowledge sustainable water usage and affordability.

In the long-run, technology has been improving water saving efficiency, in addition to achieving efficient water use of water resources by a combination of factors such as good water governance, access to capital, and technical capacity. In response to the increased demand for industrial water and water pollution in the 1970s, Japan improved water-saving technologies and technologies to address water pollution. Through its efforts, Japan has achieved efficient use of water resources, sustainable economic development, and consumption growth (METI, 2008). Technical capacity has contributed to further development and sustainability of water and environmental sanitation field. Today, Japan is a world-class leader in water technologies; for example, Japan has the largest shares in membrane technology in the world, producing 60% of membranes used in water treatment in the world. Japanese membrane technology is used in seawater desalination and advanced treatment, including wastewater recovery worldwide. (MLIT, n.d.a). Advanced technologies have brought about profits to the Japanese government and Tokyo government, allowing TMG to continue upgrading its technology and equipment while expanding its overseas operations.

Japan still has one of the highest GDP per capita, despite water shortages, compared with international standards. High industrial wastewater recycling rate (about 80%) has reduced unnecessary revenue losses due to water leakage (also referred to as non-revenue water rate) and other problems (METI, 2008). The average non-revenue water rate in Asia is 34%, compared with 3% in Tokyo and 7% in Osaka, suggesting that water systems in Japan are relatively efficient (TMG, 2019). The Tokyo government has greatly reduced water security problems caused by the water shortages through the establishment of highly efficient water delivery facilities. For example, there are link facilities between the Tonegawa and Arakawa river systems (Figure 11.), which are rivers that supply approximately 80% of water resources in Tokyo. If there are any water quality problems or an anticipated dry spell is predicted to occur in the water systems of the Tonegawa and Arakawa rivers, the raw water of the Tamagawa River water system can be effectively used through transmission, thereby effectively reducing the water security problems caused by dry spells (TMG, 2019). The Tokyo case proves that through water delivery facilities and industrial technology, it is possible to overcome difficulties and develop the economy with limited water resources (METI, 2008).

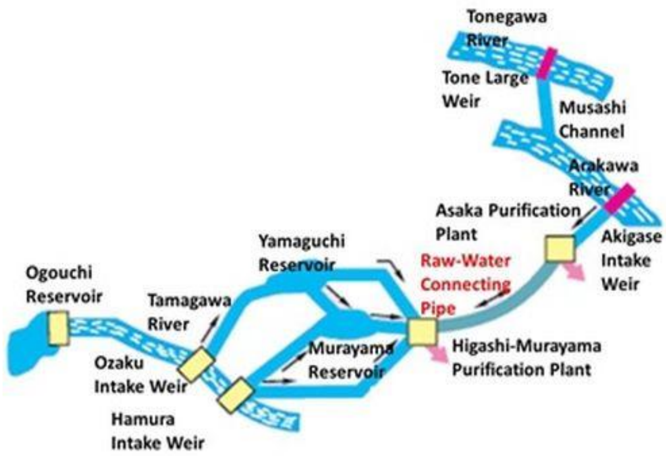


Fig 11. Linking facilities between the Tonegawa and Tamagawa systems (TMG,2019)

6. Conclusion

It is clear after conducting a background review of urban water security in Tokyo that although Tokyo is facing threats of dry spells, climate change, and vulnerability to natural disasters; through continuous improvement of its water infrastructure and conservation measures, combined with advanced technology and knowledge, different actors in Tokyo have effectively reduced the hidden dangers of water scarcity and managed to secure water supply.

7. Recommendations

Although efforts have been made at the private and public level to harvest rainwater (CSE, n.d.), these efforts could be further expanded by the government by educating the public on the benefits of harvesting rainwater. Generally, rainwater is channeled into sewers and the potential of using rainwater as a water resource has been ignored. The annual rainfall that the Tokyo Metropolitan area receives is 2.5 billion m^3, and this amount exceeds the total water consumed by the region which is 2 billion m3. This rainwater should be considered a resource and should be actively utilized (Murase, 2013). The government should mandate rainwater harvesting and provide rebates to buildings that harvest rainwater and store it for usage. This approach would help in reducing burden on the city's water supply and wastewater systems. In addition to this water demand increase could be avoided by encouraging organizations and households to adopt water conserving measures such as water-efficient appliances, water-saving plumbing fixtures, etc.

In terms of water security during water shortages or disasters, to supplement each other, both large-scale water systems and locally distributed water supply systems should be expanded within the sustainable urban water supply systems (Yamashita, 2018). Additionally, with climate change, as extreme weather events become more frequent and severe, city-to-city knowledge exchanges will also play a vital role in developing best practices to adapt to risks (IWA, 2018).

References

Anderson, C. R., Berdalet, E., Kudela, R. M., Cusack, C. K., Silke, J., O'Rourke, E., ... & Paige, K. (2019). Scaling up from regional case studies to a global harmful algal bloom observing system. *Frontiers in Marine Science.*

APFM. (n.d.). Japan Water Agency. *Associated Programme on Flood Management (APFM)*. Retrieved from: https://www.floodmanagement.info/portfolio-item/japan-water-agency/

Bureau of Environment. (2018). Water Quality Control. *Bureau of Environment - TMG*. Retrieved from: https://www.kankyo.metro.tokyo.lg.jp/en/pollution/quality.html

Bureau of Waterworks. (n.d.a). Questions in Regard to Water Charges. *Bureau of Waterworks, TMG*. Retrieved from: https://www.waterworks.metro.tokyo.jp/eng/faq/qa-2.html#a3

Bureau of Waterworks. (n.d.b). In order to deliver tap water in stable fashion. *Bureau of Waterworks, TMG*. Retrieved from: https://www.waterworks.metro.tokyo.jp/eng/news/archive-46/

Bureau of Waterworks. (n.d.c). Portable Delicious Water obtained from Rich Forests. *Bureau of Waterworks, TMG*. Retrieved from: https://www.waterworks.metro.tokyo.jp/eng/news/archive-47/

Cabinet of Japan. (n.d.). Ministry of Finance. *Prime Minister of Japan and his Cabinet.* Retrieved from: http://japan.kantei.go.jp/syoukai_e/e_html/zaimu/01.html

CSE. (n.d.). Rainwater Harvesting in Tokyo, Japan. *Centre for Science and Environment (CSE)*. Retrieved from: http://www.rainwaterharvesting.org/international/tokyo.htm

Google Maps. (n.d.). Tokyo Metropolitan Area. Japan. *Google Maps*. Retrieved from: https://www.google.com/maps/place/Tokyo+Metropolitan+Area,+Japan/@35.7564215,138.706083,8.44z/data=!4m5!3m4!1s0x601892b733979c7b:0x2ae9103fb5b7802!8m2!3d35.6635367!4d139.5279996

Furumai, H. (2008). Rainwater and reclaimed wastewater for sustainable urban water use. *Physics and Chemistry of the Earth*, *33*(5), 340-346.

Furumai, H. (2016). Evaluation of rainwater harvesting and use potential considering climate change in Arakawa watershed. *Modélisation/Models-Réutilisation des eaux pluviales/Stormwater reuse*. Retrieved from: https://www.researchgate.net/publication/222991185_Rainwater_and_Reclaimed_Wastewater_for_Sustainable_Urban_Water_Use

IWA. (2018). Tokyo endorses the International Water Association's Principles for Water-Wise Cities. *International Water Association (IWA)*. Retrieved from: https://iwa-network.org/news/tokyo-endorses-the-international-water-associations-principles-for-water-wise-cities/

IWA. (2019). Tokyo Report - Conclusions, Key Messages and Outcomes. World Water Congress & Exhibition 2018. *International Water Association (IWA)*. Retrieved from: https://iwa-network.org/wp-content/uploads/2019/10/2018_IWA_WWCE-Tokyo_Report.pdf

Jacob, D. P., Jennifer, C. V., Matthew, Z. & Aaron, T. W. (2013). Case Studies on Water Security: Analysis of System Complexity and the Role of Institutions. *Journal of Contemporary Water Research & Education, 149*, 4-2.

JST. (2009). Introduction of Japan Industrial Water Association. *Japan Science and Technology Agency (JST)*. Retrieved from: https://jglobal.jst.go.jp/en/detail?JGLOBAL_ID=200905074363695694

JWWA. (n.d.). Profile Public Interest Incorporated Association. *Japan Water Works Association (JWWA)*. Retrieved from: http://www.jwwa.or.jp/jigyou/kaigai_file/JwwaProfile2017.pdf

Kaigi, N. D. D. (2009). *Dams in Japan: Past, Present, and Future*. CRC Press.

Kitamura, T. (2012). Water Environment Management in Japan. WEPA Dialogue in Sri Lanka. Ministry of Environment, Government of Japan. Retrieved from: https://www.env.go.jp/en/focus/docs/files/20120801-50.pdf

KTR. (n.d.). About. *Kanto Regional Development Bureau, MLIT.* Retrieved from: https://www.ktr.mlit.go.jp/index.htm

Lossouarn, C., Pangare, V., Fenghua, S., Lentini, E. J., Loftus, T., Dickinson, M. A., ... & Vachaud, G. (2016). Water, Megacities and Global Change. United Nations Educational, Scientific and Cultural Organization (UNESCO).

METI. (2008). White Paper Report. *Ministry of Economy, Trade, and Industry (METI)*. Retrieved from: https://www.meti.go.jp/english/report/downloadfiles/2008WhitePaper/3-4.pdf

METI. (2018). METI Releases Overseas Development Strategy of Water Industry. Retrieved from: https://www.meti.go.jp/english/press/2018/0727_001.html

McDonald, R. I., Weber, K., Padowski, J., Flörke, M., Schneider, C., Green, P. A., ... & Boucher, T. (2014). Water on an urban planet: Urbanization and the reach of urban water infrastructure. *Global Environmental Change*, *27*, 96-105.

MLIT. (2001). Shutoken Hakusyo (Metropolitan Area White Paper). Tokyo, Printing Bureau, Ministry of Finance.

MLIT. (2008). Water resources in Japan. *Ministry of Land, Infrastructure, Transport and Tourism (MLIT)*. Retrieved from: https://www.mlit.go.jp/tochimizushigen/mizsei/water_resources/index.html

MLIT. (n.d.a). Achieving Water Security in Japan and Worldwide. *Ministry of Land, Infrastructure, Transport and Tourism (MLIT)*. Retrieved from: http://www.mlit.go.jp/tochimizushigen/mizsei/water_resources/contents/Achieving%20Water%20Security%20in%20Japan%20and%20Worldwide.pdf

MLIT. (n.d.b). Japan's Experience and Technology regarding Water Resources Management. Retrieved from: https://www.mlit.go.jp/common/001040490.pdf

MOC. (2000). Kensetsu Hakusyo (Construction White Paper). Japan, Infrastructure Development Institute.

MOC. (2018). The river law with commentary by article: Legal Framework for River and Water Management in Japan. *River Bureau, Ministry of Construction, Infrastructure Development Institute - Japan*. Retrieved from: http://www.idi.or.jp/wp/wp-content/uploads/2018/05/RIVERE.pdf

MOFA. (n.d.). Disaster and Disaster prevention in Japan. Retrieved from: https://www.mofa.go.jp/policy/disaster/21st/2.html

Murakuni, S., & Dixon, J. A. (2006). Water resources management in Japan policy, institutional and legal issues. World Bank Analytical and Advisory Assistance (AAA) program. China: Addressing Water Scarcity Background Paper, (1).

Murase, M. (2013). Sustainable water strategies for new development patterns. In Environment

in the 21st Century and New Development Patterns (pp. 147-162). Springer, Dordrecht.
Nakajo, Y. (2010). A spiral approach to IWRM: the IWRM Guidelines at River Basin Level. *IAHS-AISH publication*, *338*, 145-158.
Plaza Homes Ltd. (2019). Preventative Measures against flooding in the Tokyo metropolitan area. *Plaza Homes Ltd.* Retrieved from: https://www.realestate-tokyo.com/news/tokyo-flood-prevention/
PUC. (n.d.). Corporate Profile. *Public Utility Services Center Co., Ltd. (PUC)*. Retrieved from: https://www.puc.co.jp/files/english/CorporateProfileE.pdf
Priscoli, J. D., & Hiroki, K. (2016). Drought Policies: Case Studies on Mega-droughts for the High Level Experts and Leaders Panel on Water and Disasters (HELP) Introduction.
Sato, C., Haga, M., & Nishino, J. (2006). Land subsidence and groundwater management in Tokyo. *Internat Rev Environ Strat*, *6*(2), 403.
SOUMU. (n.d.). Introduction of Kanto General Communication Bureau. *Ministry of Internal Affairs and Communications*. Retrieved from: https://www.soumu.go.jp/soutsu/kanto/
Takesada, N. (2009) Japanese Experience of Involuntary Resettlement: Long-Term Consequences of Resettlement for the Construction of the Ikawa Dam*, International Journal of Water Resources Development*, 25:3, 419-430.
TMG. (2018). Water Supply in Tokyo. *Tokyo Metropolitan Government (TMG).* Retrieved from: http://www.waterprofessionals.metro.tokyo.jp/tmwb-7.html
TMG. (2019). Tokyo Waterworks Technical Magazine Vol.7. Retrieved from: https://www.waterprofessionals.metro.tokyo.jp/files/items/27264/File/magazine-vol-07.pdf
Tomohiro, O. (2018). With water privatization, Japan faces crossroads in battling its aging pipes. *The Japan Times News.* Retrieved from: https://www.japantimes.co.jp/news/2018/12/17/reference/water-privatization-japan-crossroads-battling-aging-pipes/#.XpYZTdNKgWo
Tortajada, C. (2010). Water governance: Some critical issues. *International Journal of Water Resources Development*, *26*(2), 297-307.
Tournier, J. P., Bennett, T., & Bibeau, J. (2019). Sustainable and Safe Dams Around the World: Proceedings of the ICOLD 2019 Symposium, (ICOLD 2019), June 9-14, 2019, Ottawa, Canada. CRC Press.
TSS Tokyo Water. (n.d.a). Leak Detection and Prevention. *TSS Tokyo Water Co., Ltd*. Retrieved from: https://www.tssk.jp/eng/service/antileak/
TSS Tokyo Water. (n.d.b). Profile. *Tokyo Water Co., Ltd. (TSS)*. Retrieved from: https://www.tssk.jp/eng/company/outline.html
UN. (2015). Sustainable Development Goals Knowledge Platform. *United Nations.* Retrieved from: https://sustainabledevelopment.un.org/sdg6
UNESCO. (2009). IWRM guidelines at river basin level. Part 2-1: The guidelines for IWRM coordination. UNESCO.
UN FAO. (2017). Water for Sustainable Food and Agriculture. Retrieved from: http://www.fao.org/3/a-i7959e.pdf
UN Water. (2013). 2030 Water Secure: Developing capacity to secure the 21st century Water Risk. United Nations Water. Retrieved from: http://water-future.org/wp-content/uploads/2018/03/2030WaterSecure_web.pdf
Walton, B. (2011). After Earthquake, Millions in Japan Without Water - Extent of Damage to

Water Infrastructure Unknown. *Circle of Blue*. Retrieved from: https://www.circleofblue.org/2011/world/after-earthquake-millions-in-japan-without-water%E2%80%94extent-of-damage-to-water-infrastructure-unknown/

Yamashita, A. (2018). History of Urban Water Use in Tokyo with Focusing on Surface and Subsurface Water as Water Sources. In Tokyo as a Global City (pp. 115-135). Springer, Singapore.

Yoichi, F. & Asahi, S. (2010). Global water security: Japan should play a key role. *East Asia Forum.* Retrieved from: https://www.eastasiaforum.org/2010/09/15/global-water-security-japan-should-play-key-role/