



## **Learning from Japan's Experience in Integrated Urban Flood Risk Management: A Series of Knowledge Notes**

### **Knowledge Note 4: Operating and Maintaining Urban Flood Risk Management Investments**



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Cover Image: Futakotamagawa Rise and Park in Setagaya Ward, Tokyo—a multipurpose, public, private, and community-led urban redevelopment project that integrates nature-based solutions to mitigate river and surface water flooding.

(Photo Credit: Kenya Endo)

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## 1. Summary

**Operation and maintenance (O&M) are critical to ensuring the effectiveness of urban flood management investments over time.** In the context of human and financial resource constraints, Japanese cities must enhance O&M to extend the functional lifetimes of critical investments. While these cities have been able to mobilize financial and technical resources needed to design and implement a wide range of flood management investments (as described in **Knowledge Note 3**), today many are faced with a large stock of aging infrastructure that was developed during the rapid urbanization of the 1950s–1960s. As Japan’s population shrinks and labor costs increase, there is an urgent need to improve the quality and efficiency of O&M for existing as well as newly developed urban flood risk management investments.

**This Knowledge Note highlights the Japanese practice of using O&M to sustain and enhance the functionality and efficacy of urban flood risk management investments.** This Note focuses on two phases of O&M practice in Japan namely: (i) planning and implementation, such as regular inspections, maintenance, repairs, and replacement work; and (ii) performance monitoring and evaluation, such as regular performance reviews and analysis of data on assets and related indicators. Japanese cities have accumulated various lessons and good practices in how to improve the sustainability and effectiveness of their integrated urban flood risk management (IUFRM) investments. Based on a review of O&M efforts across several Japanese cities (see **appendix** for a full list), this Note summarizes: (i) key approaches to the O&M of urban flood risk management investments in Japan, and (ii) enabling factors, including various tools and measures that may be used to improve the effectiveness and efficiency of O&M.

**Based on the Japanese context and lessons learned, key considerations that support the effective O&M of flood management investments include the following:**

- **A policy and institutional framework** that outlines the required O&M approach and activities for a facility, key performance indicators, monitoring and evaluation mechanisms, as well as the roles and responsibilities of various stakeholders
- **Human resources** with appropriate knowledge and skills to implement O&M plans and procedures, and technical expertise and ability
- **An investment design** that takes into consideration O&M requirements and their ease of implementation;
- **Financial resources** to carry out O&M activities, and cover the costs of required repairs, replacement, personnel, training as well as research and development of new technologies to enhance flood management and O&M

**Japanese cities are using various tools and measures to perform effective O&M.** This Note highlights some of the key ones:

- **Technical guidelines and manuals** for the O&M of flood management facilities have been developed by the national government (Ministry of Land, Infrastructure, Transport and Tourism, MLIT) and technical institutes (i.e., Japan Institute for Wastewater Engineering and Technology, Japan Sewer Collecting System Maintenance Association, etc.). These documents clarify the institutional roles and help to ensure that technical standards for various types of flood management investments are clearly defined, monitored, and met over time so that these investments fulfill their intended functions and objectives. Given that there are a variety of flood risks, and associated measures are implemented by a diverse range of stakeholders in Japan, using a variety of methods, the public sector, as well as technical institutes and professional associations, play a key role in consolidating the knowledge and expertise available, reviewing and screening the approaches, and sharing recommended guidelines and approaches required for effective O&M.
- **Monitoring and management plans** have been developed and implemented by facility owners. Well-established schedules, stakeholder roles and responsibilities; mechanisms and measures for replacement, repairs, evaluation, budgets, and monitoring; and management plans help facility owners operationalize necessary O&M activities throughout the lifetime of an investment. Asset management databases are often developed and utilized to gather, analyze, and evaluate performance indicators over time.

- **The engagement of various stakeholders** enables the sharing of roles, responsibilities, and financing for O&M. New ways of designing projects and updating the policy and legal framework to clarify and enable private sector and community engagement in the O&M of flood management facilities are emerging alongside the development of multipurpose and multifunctional flood risk management investments. Key steps include establishing legal frameworks at the municipal level for public-private partnerships (PPPs) and private finance initiatives (PFIs),<sup>1</sup> as well as coordinating urban development and the process of upgrading flood risk management facilities, and sharing various roles and responsibilities. Enhanced community participation can also lead to improved awareness and the better management of flood management infrastructure.
- **Innovative O&M technologies** are being used to implement O&M activities more efficiently and effectively, minimizing the time and other resources needed for O&M during the lifetime of an investment. Regular local activities, such as seasonal community cleanup efforts, as well as community-based rainwater harvesting and management groups can enable the access to information, resources, and support necessary to ensure not only the uptake of urban flood management investments but also the O&M and long-term sustainability of these initiatives.

## 2. O&M of Urban Flood Risk Management Investments

**Japanese cities today face the challenge of maintaining the effective operation of their extensive yet aging flood risk management infrastructure.** For example, in 2016, MLIT reported that out of the approximately 470,000 kilometers (km) of sewerage pipes that service cities across Japan, approximately 14,000 km (3 percent of the total length) were older than 50 years (MLIT n.d.[b]). The share of pipes older than 50 years is projected to increase to 57,000 km (12 percent) by 2026, and 140,000 km (30 percent) by 2036. Additionally, in 2016, out of 1,500 stormwater pumping stations, more than 1,200 stations (77 percent) were reported to have been in operation for more than 20 years. Considering the condition of their infrastructure, Japanese cities need to implement long-term O&M to sustain effective flood risk management functions. While this is particularly true for Japan and relevant to other developed economies with mature infrastructure, lessons learned from Japan can also inform the efforts of developing countries, particularly as they seek to improve the life-cycle design of their infrastructure.

### 2.1 Institutional Framework for O&M

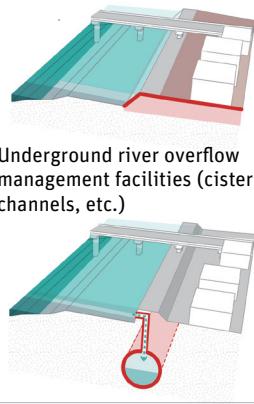
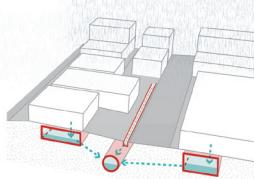
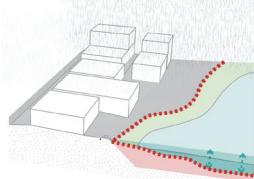
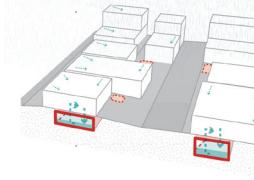
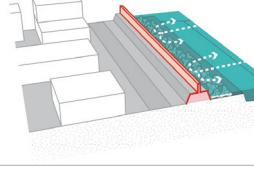
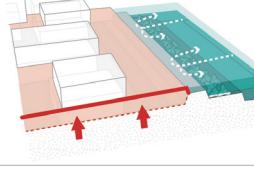
**With a common goal of mitigating urban flood risk, Japan's national and local governments, private sector, and citizens share responsibility for the O&M needed to sustain IUFRM investments.** Institutional roles and responsibilities for specific O&M tasks are delegated based on the context, including the roles of facility managers, required expertise, and technologies. In some cases, an O&M management agreement between stakeholders and related organizations is signed before O&M begins. In general terms, prefectures and municipal governments are responsible for installing stormwater storage and infiltration facilities and conducting related O&M in areas under their respective jurisdiction.<sup>2</sup>

**The location, scale, and function of investments, and the requirements for technical knowledge may also inform which entity will most effectively and efficiently lead the O&M of flood management investments.** To ensure efficiency, organizations and personnel with the appropriate expertise, knowledge, and skills need to be encouraged to engage. For example, small-scale, decentralized rainwater harvesting systems and rain gardens may be best operated and maintained by community groups or households, supported by training in the required knowledge and skills. On the other hand, large-scale gray infrastructure, such as embankments and extensive underground drainage pipe systems, require specialized knowledge and authorization, as well as substantial financing best suited for the public sector to lead. Further, and as in other countries, for larger structural initiatives, responsibilities can often be transferred from the national government to local governments between the construction and O&M periods. **Figure 1** provides an overview of the responsible entities for each flood and investment type. This is followed by

<sup>1</sup> Since 1999, Japan has enacted the “Act on Promotion of Private Finance Initiatives” and promoted initiatives to crowd in private finance in partnership with public sector initiatives (Cabinet Office of Japan n.d.).

<sup>2</sup> Refer to Knowledge Note 2, Table 1, for an overview of institutional responsibilities across different phases of urban flood risk management.

**Figure 1: Entities Responsible for the O&M of Urban Flood Risk Management Investments in Japan**

Flood type	Investment	Responsible entity
River flood	<p>River embankments</p>  <p>Underground river overflow management facilities (cisterns, channels, etc.)</p> 	 
Surface flood	<p>Underground stormwater management facilities (cisterns, channels, drainage pipes, culverts, etc.)</p>  <p>Stormwater detention ponds, parks, and gardens</p>  <p>Rainwater harvesting systems (collection systems and storage tanks installed in public, commercial, community buildings)</p> 	     
Storm surge flood	<p>Seawalls and gates</p>  <p>Ground raising</p> 	 
Combined / All	<p>Risk assessment, land use plans, zoning, and building codes</p> <p>Enhancing early warning systems</p>	  



National government



Municipal government



Facility manager (public or private)



Community

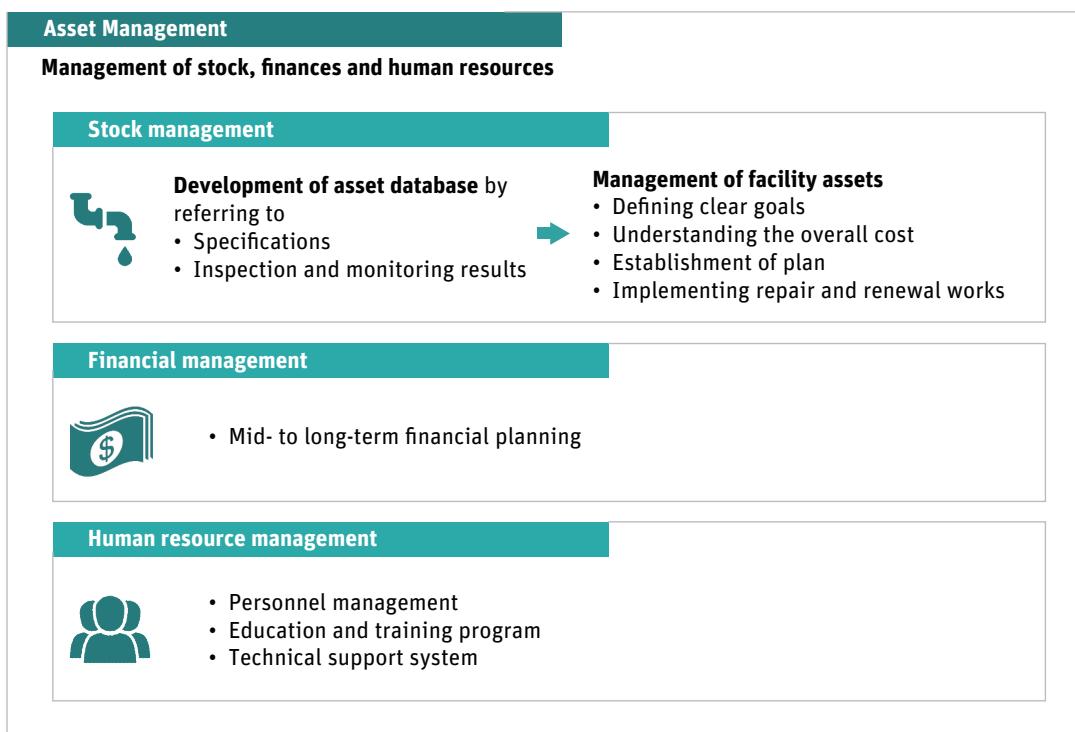
Sources: Authors' compilation.

a discussion of the two phases of O&M—(i) planning and implementation and (ii) performance monitoring and evaluation—and the institutional arrangements in place for them.

## 2.2 Planning and Implementation of O&M Activities

**In Japan, approaches to the management of assets and stock are included in long-term infrastructure plans that support effective operations with limited human, material, and financial resources.** The national government provides policy, technical support, and guidance, and sets standards for O&M. Facility managers, including local government agencies and private sector stakeholders, own, operate, and maintain investments on a day-to-day basis. For example, to promote the management of assets in sewerage investments, MLIT has developed various policy instruments such as the New Sewerage Vision (2014), Revised Sewerage Act (2015), and Stock Management Support Mechanism (2016). In line with these national policies, financial and technical assistance is provided to facility managers to support effective O&M (MLIT n.d.[a]). **Figure 1** outlines the entities responsible for the various urban flood risk management investments implemented in Japan. As defined by MLIT, the management of a facility's assets and stock encompasses the financial and human resources required for O&M (see **figure 2** for a conceptual diagram) and enables sustainable, efficient, and strategic operations by defining clear goals based on an objective analysis and evaluation of the entire system.

**Figure 2:** Overview of Asset and Stock Management



Source: MLIT n.d.(a).

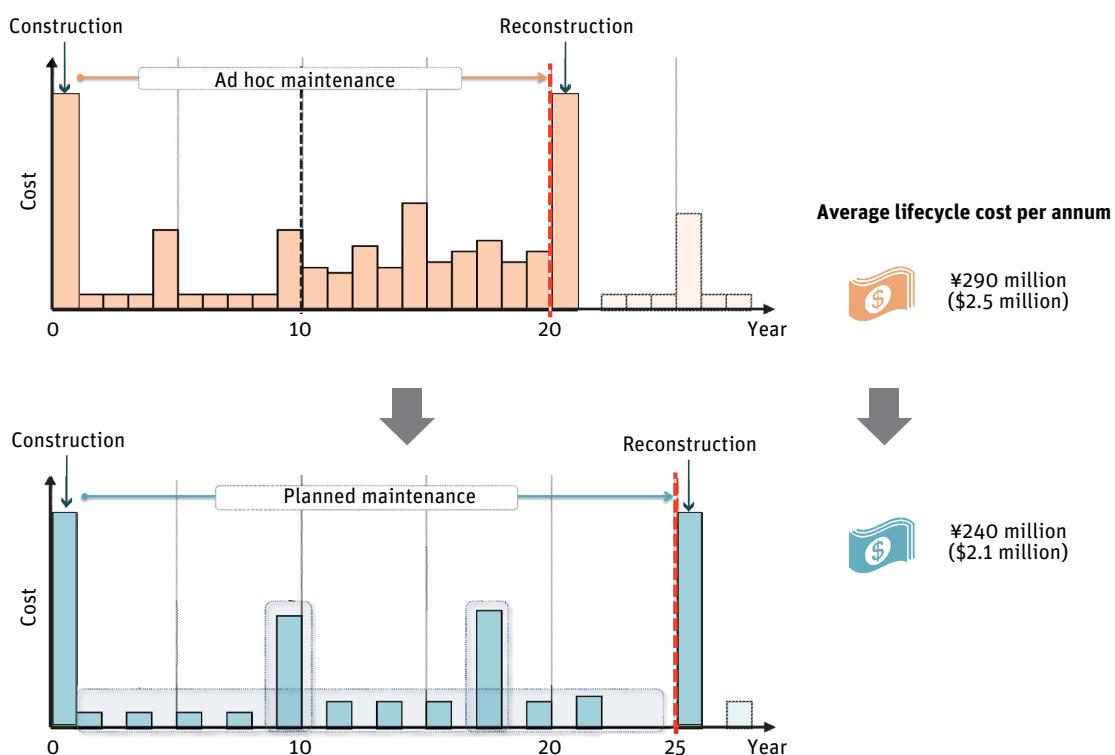
**For example, for sewerage facilities, managing assets would entail examining the entire life cycle of facilities and equipment so that preventative maintenance can be implemented strategically from the planning and design stages.** Property is maintained systematically and efficiently while considering the life-cycle costs and harmonizing operations with medium- to long-term restructuring activities. Projected operations are based on the useful economic life of a facility, or the number of years the facility can be operated for a minimal annual cost, calculated by dividing the total cost (that is, the life-cycle cost, including construction and O&M) by the number of years of operation. Properly maintained sewerage facilities will have longer life cycles than their estimated service lives and can be reconstructed more efficiently.

The MLIT's guidelines for managing the O&M of flood risk management investments in Japan include the following steps:

- **Gather information** on facilities
- **Decide** the priorities for inspection and repair and maintenance work
- **Set performance targets for facility management**, including both repair and replacement work
- **Model long-term repair and replacement scenarios** that allow planners to compare various conditions and management methods
- **Conduct regular inspections and maintenance** according to set standards and in line with plans (target facility, scope, measures to extend facilities' lifetime, schedules, costs, etc.)
- **Periodically evaluate plans and approaches**, and adjust them as needed

**The Tokyo Metropolitan Government (TMG<sup>3</sup>) is implementing proactive O&M of its extensive and aging sewerage facilities, using the asset management methods described above across its 23 central wards.** TMG, together with MLIT, is working to extend the service life of Tokyo's sewerage systems from their design life of 50 years to 80 years (Bureau of Sewerage, TMG 2017). To this end, it is implementing cost-effective repair and reconstruction work in partnership with various sectors and stakeholders. A comprehensive and regularly updated **asset database** helps monitor progress against TMG's business plan and is instrumental in prioritizing and implementing required O&M work on the 16,000 km sewerage network. The database includes information on pipe locations, depths, installation years, and types. This large set of **geospatial information** is complemented by monitoring and inspection data, as well as plans for the renewal of aging sewerage facilities (Morikawa 2018). By monitoring the degree of deterioration at each facility, for example, TMG can allocate appropriate time and financial resources to reconstruction work. As a result, the life cycle of facilities has been extended, and unnecessary remodeling has been reduced, lowering O&M costs and thus increasing the cost-efficiency of O&M. For example, as shown in **figure 3**, by planning repairs more efficiently, the annual average life-cycle cost has been reduced by about 20 percent (from ¥290 million/year to ¥240 million/year, or \$2.5 million/year to \$2.1 million/year). Further information on TMG's management of its sewerage assets is included in the appendix (case 16).

**Figure 3: Life-Cycle Cost Savings Due to Careful Management of Sewerage System Assets in Tokyo's 23 Central Wards**



Sources: Bureau of Sewerage, TMG 2016b.

## 2.3 Performance Monitoring and Evaluation

**Performance monitoring and evaluation processes are critical to help to track the effectiveness of investments in relation to their long-term flood risk management capacities and functions.** In Japan, these processes are specific to each type of flood risk management investment. Facility managers typically follow guidelines developed by MLIT, municipal governments, and/or technical agencies. The various types of guidelines developed for different flood risk management investments are described in section 4.1. While the specific processes and criteria for monitoring and evaluation vary between investments, in general:

- Performance monitoring includes the (i) identification of expected performance levels during design, and (ii) regular and consistent gathering of data to be used as performance indicators.
- Evaluation involves (i) analysis of results against the target, (ii) identification of problems and corrective measures as needed, and (iii) updating of O&M plans and other key facility operation and management frameworks.

**In 2010, MLIT established detailed draft guidelines for monitoring and evaluating the performance of stormwater infiltration facilities** (MLIT 2010). These include ways to calculate stormwater infiltration estimates, review and update facilities' infiltration capacity by analyzing collected data and simulation models, incorporate quantitative information in planning processes, implement effective O&M, and conduct monitoring and evaluation.

**Similarly, MLIT has outlined the basic principles and key elements of monitoring river embankments** (MLIT 2004). The function of an embankment is to mitigate water penetration and erosion. This monitoring is generally undertaken to (i) identify and observe locations in critical need of attention, and (ii) assess the performance of fortification technologies. Facility managers then gather and organize this information and technical safety standards to define the timing, methods, and other specifics of O&M activities.

**In Japan, private sector entities have also led efforts to establish and enhance the monitoring and evaluation of flood management facilities, together with the public sector.** For example, the Urban Renaissance Agency (UR) is a public and independent administrative agency in Japan that supplies rental housing in large cities. Through this work, UR aims to provide environmentally and socially attractive spaces for living that are resilient to natural disasters. Flood risk management, therefore, is a key consideration in its housing and urban development initiatives. As such, UR has been monitoring and evaluating the performance of its investments over time.

**In housing development initiatives such as Akishima Tsutsujigaoka Collective Housing (appendix, case 17) in 1977 and Hachioji Minamino City (appendix, case 14) in 1986, UR combined green and gray solutions to manage flood risk. In both cases, UR monitored the amount of rainfall and the flow rate during implementation, and demonstrated through quantitative data that its integrated approach significantly reduced stormwater runoff.** O&M is usually conducted by a public entity (e.g., the city government) that assumes ownership of a completed facility from the developer. However, in these two cases, UR has overseen O&M management for more than 20 years following project completion, conducting monitoring, analysis, and impact assessment of stormwater runoff control facilities. UR's efforts to proactively collect data and analyze how its investments were able to achieve and sustain flood management capacity have, in turn, lightened the burden of municipal governments (as the facility managers).

UR's monitoring and evaluation results in these two cases are outlined in **box 1**. Further information is also available in the appendix (cases 14 and 17).

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<sup>3</sup> Tokyo is a regional government encompassing 23 special wards, 26 cities, 5 towns, and 8 villages. However, reflecting the dense population, urban contiguity, and other realities of the 23 special ward area, a unique administrative system exists between the metropolitan government and the wards, which differs from the typical relationship between prefectures and municipalities. This system balances the need to maintain unified administration and control across the whole of the ward area and the need to have the local ward governments, which are nearer to the residents, handle everyday affairs. Specifically, in the 23 wards, the metropolitan government takes on some of the administrative responsibilities of a "city," such as water supply and sewerage services, and firefighting, to ensure the provision of uniform, efficient services, while the wards have the autonomy to independently handle affairs close to the lives of the residents such as welfare, education, and housing (TMG n.d.).

## Box 1: Monitoring and Evaluating the Impact of Flood Risk Management in Two Urban Housing Development Initiatives

### Akishima Tsutsujigaoka Collective Housing, Akishima City, Tokyo

To meet the growing challenge of urban floods due to the rapid post-1950s urbanization of the Tokyo Metropolitan Area, in 1977 the Urban Renaissance Agency (UR) and the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) embarked on a bold experimental initiative. They set up the first rainwater infiltration system in Japan, at the Akishima Tsutsujigaoka Heights Housing Complex, a 27.8 hectare (ha) residential neighborhood that was home to 2,673 families (Satomi 2013). System components included infiltration containers (49 items), an infiltration trench (494 meters [m] in length), an infiltration U-shaped gutter (143 m in length), and a permeable pavement (3,580 square meters [ $m^2$ ] in area) (Hayashi, Shimada, and Morikami 2002).

#### Monitoring and Evaluating Results

As illustrated in **figure B1.1**, Akishima Tsutsujigaoka Collective Housing was divided into a northern block (1.32 ha), where infiltration measures were installed, and a southern block (1.86 ha), which was managed by normal drainage systems only and where infiltration measures were not installed. In order to compare the stormwater runoff volume of the two blocks, one rain gauge and three flowmeters were set up, and monitoring started in 1981. Changes over the years to the average runoff coefficients of the two blocks (due to changes in land use) were confirmed to be similar (northern block with intervention: 0.65; southern block without intervention: 0.64).

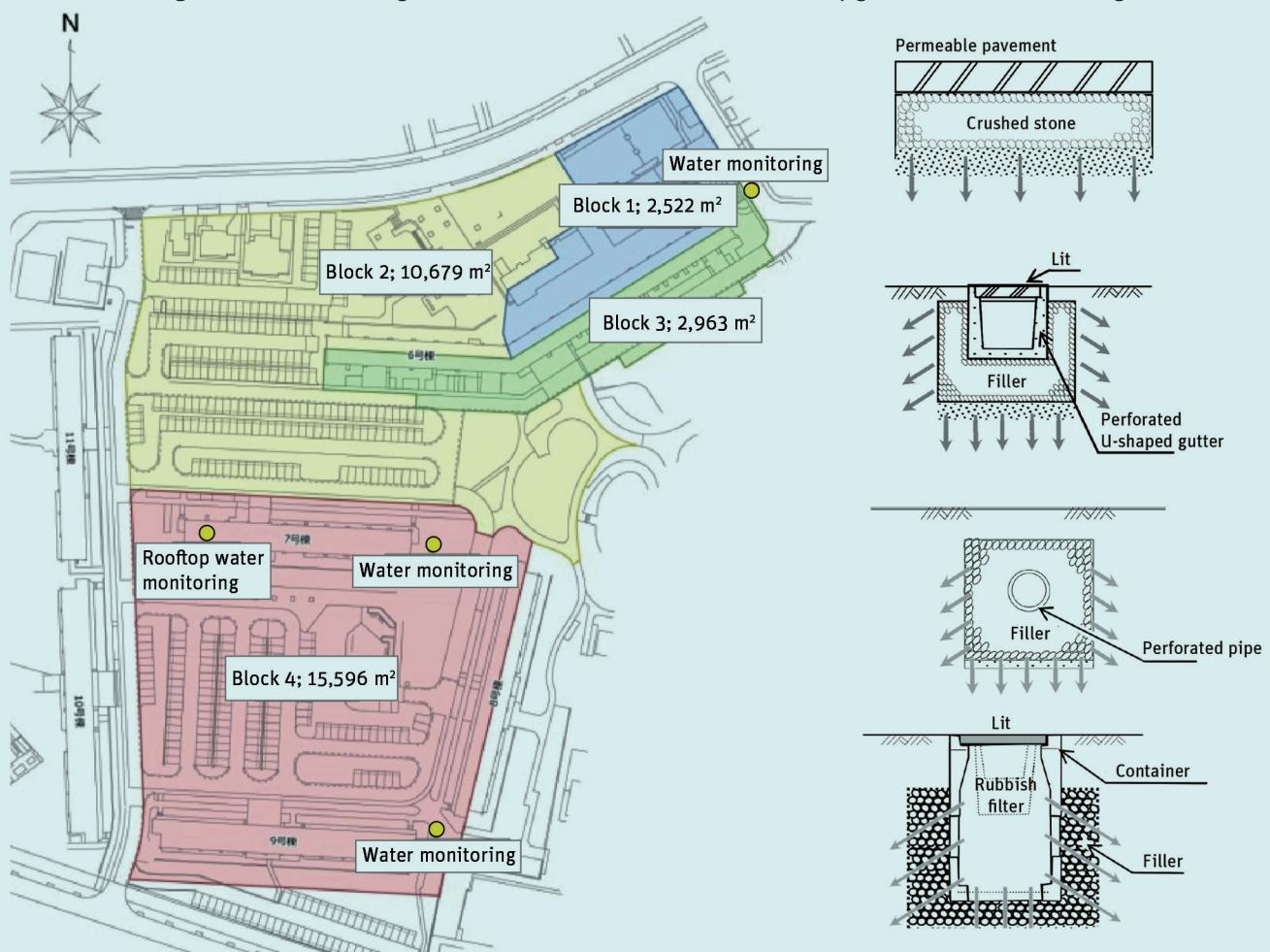
Between 1981 and 2000, data on instances of a total rainfall of 30 millimeters (mm) and above, or a peak rainfall of 10 mm/30 minutes or above, were gathered and analyzed. It was found that 109 events met these criteria over the 20-year study period. The analysis also revealed that:

- **The infiltration facility sustained its flood management function over 20 years.** The runoff rate over 20 years remained at around 0.1 for the northern block (that is, with the intervention). Furthermore, its performance under short, concentrated heavy rain, as well as a long, larger total volume of rain was shown to be equally effective, and the performance level did not change over the 20 years of observation.
- **The urban flood risk management capacity of those areas where the intervention had been implemented was significantly higher than in areas without the intervention.** The average runoff rate over the 20 years for the northern block with the intervention was 0.11. This was approximately 20 percent of the average of the southern block without the intervention.

The effects of groundwater recharge from the infiltration measures were also monitored and assessed utilizing a simulation model (Similar Hydrologic Element Response [SHER] model), with the following results:

- **The infiltration facility had a significant groundwater recharge effect.** Through the model, one-year rainfall in 2000 was set at 100 percent, and used to estimate the groundwater recharge volume, evapotranspiration volume, and surface water runoff volume for land before development (natural land), area with infiltration facilities, and area without infiltration facilities. The underground water recharge volumes for the northern block with investment and southern block without investment were found to be 50 percent and 24 percent, respectively. This indicated that the groundwater recharge capacity in areas with infiltration investment was twice that of areas without the investment.
- **The infiltration facility contributed significantly to reducing surface water runoff.** Furthermore, surface water runoff volume was also 9 in the block with the investment and 54 in the area without the investment, demonstrating that infiltration measures contributed toward a 80 percent reduction of the runoff.

These evaluations were further followed up in 2017, when it was shown that the flood management and groundwater recharge effectiveness of the investments were sustained even after 30 and 35 years of implementation, as illustrated in **figure B1.2**.

**Figure B1.1:** Monitoring and Evaluation Area at Akishima Tsutsujigaoka Collective Housing

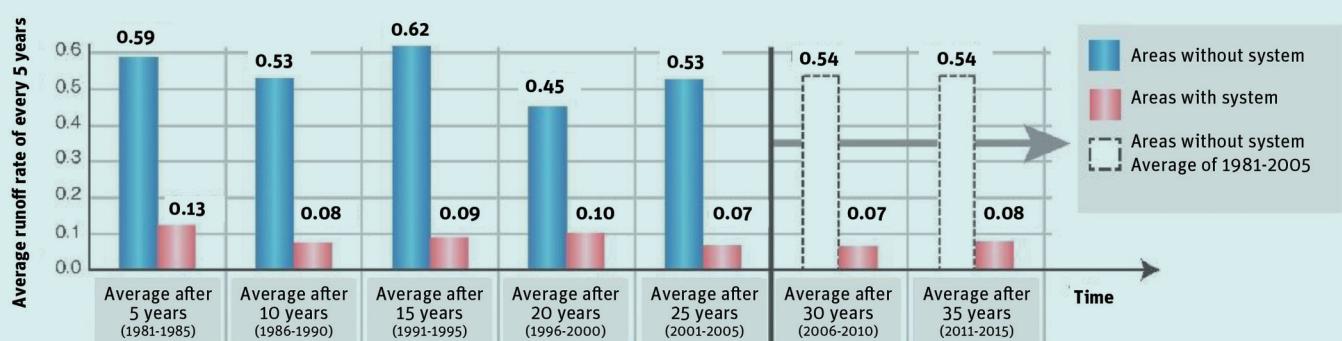
Source: Satomi 2013; Hayashi, Shimada, and Morikami 2002.

Note:  $\text{m}^2$  = square meter.

**Figure B1.2:** Impact of the Stormwater Infiltration System in Akishima Tsutsujigaoka Collective Housing

Even after 35 years, the rainwater infiltration system is still moistening the earth and controlling the runoff of rainwater.

**Runoff rate: the ratio of surface runoff to total rainfall.**



Source: UR N.d.(b).

### Hachioji Minamino City, Tokyo

Similar to Akishima City, Hachioji Minamino City was developed as a new large-scale (394.3 ha) residential neighborhood to accommodate Tokyo's growing urban population between 1986 and 1997. When the project was proposed, significant concerns were raised by residents and the academic community regarding its potential impact on the environment and associated risks of urban floods. In response, a Committee on the Hydrological Cycle Conservation System for Hachioji New Town was formed with participation from the national and local governments, the developer (UR), academia, and citizens. Discussions led to the development of a water circulation and restoration system (Tamura et al. 2007). As part of this system, various pioneering flood mitigation and stormwater storage measures were implemented at that time. The committee played an instrumental role in the system's design, incorporation, monitoring, and evaluation.

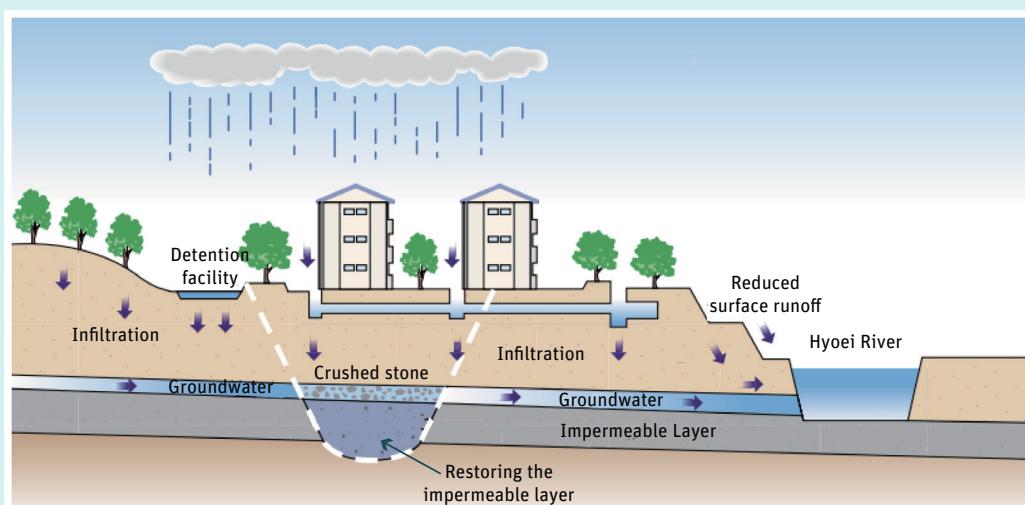
System objectives were threefold, touching upon the various aspects of water circulation, including: (i) managing flood risks through reducing stormwater runoff, (ii) enhancing groundwater recharge, and (iii) reducing drought risks through water storage. Stormwater runoff management measures included expanding river channels and sewer drainage, as well as on-site and off-site storage and infiltration facilities. These facilities also aimed to enhance the groundwater recharge. Drought management investments included the construction of permeable embankments, groundwater collection engineering, securing and utilizing spring water and water from detention ponds, and appropriate maintenance (i.e., avoiding leakages) of low-lying canals.

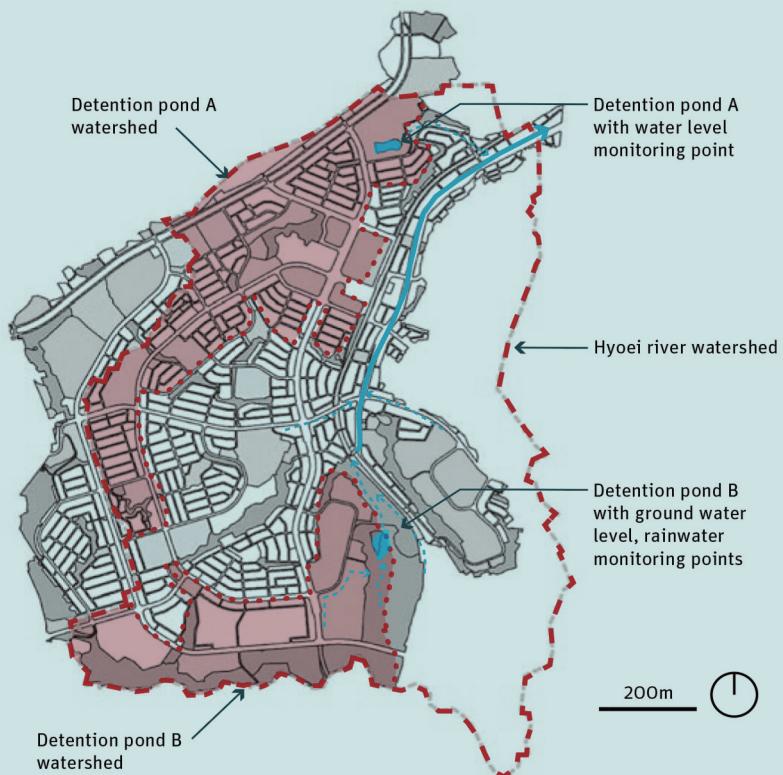
#### Monitoring and Evaluating the Multifaceted Impact of the Intervention on Water Circulation

In order to monitor and assess the effectiveness of these investments, the flow volume of the Hyoei River, the discharge volume from the detention ponds, rainfall values, etc. were gathered starting in 1996. Data analysis using the SHER model and utilizing information from 1996 to 2012 found that:

- Infiltration measures sustained the drought management function.** Despite the change in land use due to development, the flow level of the Hyoei River was sustained above the basic level over the observed period. Additionally, although annual variation was observed due to changing rainfall patterns, the average water flow of the Hyoei River during the dry season remained consistent at around 881 cubic meters ( $m^3$ ) (UR n.d.[a]). The observed drought management capacity from the water circulation and restoration system (14 percent) exceeded the estimated design level (10 percent).
- Stormwater storage and infiltration measures lowered stormwater runoff.** Although rainfall increased significantly after 2005–07, for rainfall over 10 mm/hour that was observed over the 16-year period the runoff rate increased only minimally and remained close to 0.6 percent, which was within the scope of the design rate.
- Detention ponds** helped manage approximately 2–4.5 mm/hour rainfall with 10,000–18,000  $m^3$  total storage capacity.

**Figure B1.3:** Monitoring and Evaluation Area at Hachioji Minamino City

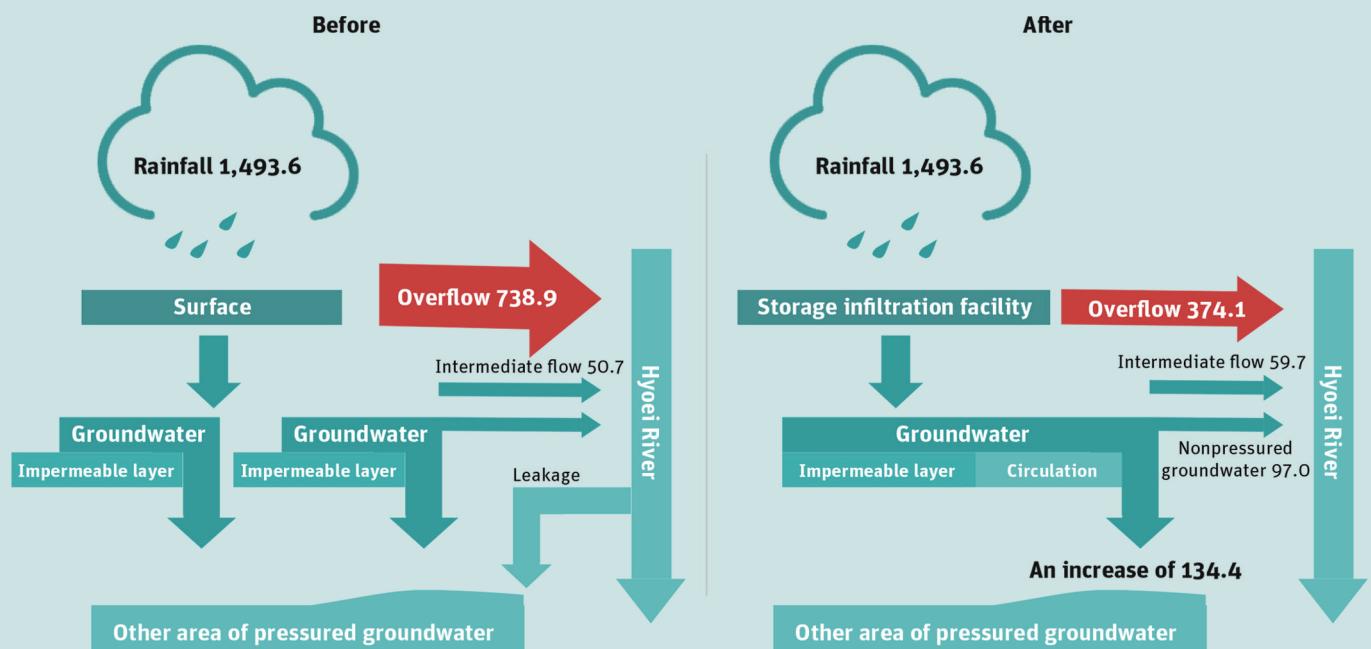




Source: UR 2008, n.d.(a); Tamura et al. 2007.

Note: m = meter.

**Figure B1.4:** A Comparison of Annual Water Balance before and after Stormwater Storage and Infiltration Measures



Source: UR 2018.

### 3. Enabling Factors for Effective O&M

**There are a number of enabling factors critical for effective O&M, as listed in table 1.** Along with the institutional arrangements described above as they relate to the two phases of O&M—that is the design and decision-making process, and the asset and stock management approaches—IUFRM investments are analyzed against various criteria that enable effective O&M. Specific examples of how these enabling factors play out are described in the following sections: (i) guidelines and manuals; (ii) monitoring and management plans; (iii) engagement of various stakeholders; and (iv) innovative technologies, as visualized in **table 1**. Although the flood risk type and the unique contexts of each urban flood risk management investment vary significantly, some common tools and approaches have been trialed over the years to enable sustainable and effective O&M.

**Table 1:** Enabling Factors, Tools, and Approaches for Effective O&M

<b>Enabling Factors for O&amp;M</b>		<b>Description</b>			
		<b>Tools and Approaches</b>			
		<b>Guidelines and Manuals</b>	<b>Monitoring and Management Plans</b>	<b>Engagement of Various Stakeholders</b>	<b>Innovative Technologies</b>
	<b>Policy and institutional frameworks</b> outline the required O&M approach and activities, key performance indicators, monitoring and evaluation mechanisms, as well as the O&M roles and responsibilities of various stakeholders	Having clear and effective governance mechanisms and policy incentives for O&M such as regulations, subsidies, assistance, management agreements, etc. are needed to ensure effective and regular O&M. Public, private, and community stakeholders all have a significant role to play in promoting efficient and sustainable O&M mechanisms for IUFRM investments. For example, <b>figure 6</b> provides an example from the implementation of the Futakotamagawa Rise and Futakotamagawa Park Project, where O&M responsibilities were shared between the government, private developers, tenants, and community members, through a combination of policy incentives and collaboration.			
		<b>Describe and elaborate</b>		<b>Require</b>	
	<b>Human resources</b> include appropriate knowledge and skills to implement O&M plans and procedures	The engagement of various stakeholders, together with asset owners and managers, could enhance the effectiveness and sustainability of O&M as well as flood management investments. Capacity building, training, and clear guidance on O&M procedures is needed for securing diversified human resources for O&M.			
		<b>Guidelines and Manuals</b>	<b>Monitoring and Management Plans</b>	<b>Engagement of Various Stakeholders</b>	<b>Innovative Technologies</b>
			<b>Ensure and monitor</b>		<b>Support and require</b>
	<b>Investment design</b> takes into consideration requirements and ease of O&M	Considering the frequency, types, and resources needed for repair, replacement, and reconstruction while selecting the investment design is important. Therefore, exploring various ways to lower the O&M cost, extend service life, and as a result reduce life-cycle costs for the investment, is a key design consideration.			
		<b>Guidelines and Manuals</b>	<b>Monitoring and Management Plans</b>	<b>Engagement of Various Stakeholders</b>	<b>Innovative Technologies</b>
		<b>Inform</b>			<b>Enable</b>

Enabling Factors for O&M	Description
	<p><b>Financial resources</b> are available to cost-effectively carry out necessary O&amp;M activities throughout the life cycle of the investment</p> <p>Securing financial resources and reducing the costs of O&amp;M activities will affect the sustainability of IUFRM investments. Preventive maintenance and asset management not only prolong the service life of facilities, but also lower the life-cycle costs. <b>Box 2</b> provides an example from Tokyo of the financial resources mobilized for the O&amp;M of sewerage facilities in the Tokyo Metropolitan Government area, which serves a critical role in managing urban floods in dense urban spaces. In <b>section 4</b>, specific examples of cost-sharing arrangements between the public sector, private sector, as well as citizens and communities are provided.</p>
Tools and Approaches	
Guidelines and Manuals	Monitoring and Management Plans
	<p><b>Ensure and monitor</b></p>
Engagement of Various Stakeholders	Innovative Technologies
	<p><b>Enable and increase</b></p>
	<p><b>Enable</b></p>

*Source:* Authors' compilation.

*Note:* IUFRM = integrated urban flood risk management; O&M = operation and maintenance.

### 3.1 Guidelines and Manuals

In Japan, government agencies, technical institutes, and industry associations, among other entities, have developed guidelines and manuals to not only inform the technical design but also the actions needed for effective O&M of IUFRM investments implemented in cities across the country. These guidelines and manuals provide a clear policy and institutional framework in setting standards, design levels, and minimum requirements, etc. They specify the proper frequency, tasks, procedures, quality control, and performance standards for O&M based on the various flood risks and investment types. This in turn helps facility developers and operators consider and integrate O&M requirements within their investment design and management plans, as well as ensure that a certain level of technical standards for facility performance is sustained over time. In addition, the standardization associated with these guides may allow third parties to take responsibility for O&M functions when needed.

For example, **TMG's technical guidelines for stormwater storage and infiltration facilities** (Tokyo Metropolitan Comprehensive Flood Control Council 2009, n.d.) require one or more periodic inspections in a year, depending on the rainy and typhoon seasons, as well as emergency inspections to conduct necessary repairs whenever a broken part is identified. At larger and more critical drainage facilities, technical inspections for preventive purposes are required daily, monthly, and annually according to the importance of the facility. For a facility that has significant impacts on citizens' lives, assets, and socioeconomic activities, inspections may be required monthly or even daily to prevent the facility from breaking down and becoming paralyzed. If the facility is not so significant, an inspection once every year is sufficient (MLIT 2016b).

The various manuals and guidelines developed in Japan for the O&M of flood management investments prepared by national and local governments, industrial organizations, as well as sectors are illustrated in **table 2**.

**Table 2:** Manuals and Guidelines for O&M, Monitoring, and Evaluation, by Flood and Investment Type

Flood Type	Investment Type	Key Guidelines and Manuals for Operation, Maintenance, Monitoring, and Evaluation	Published by
River flood 	<b>River management facilities,</b> including: <ul style="list-style-type: none"><li>• River embankments</li><li>• Underground river overflow management facilities (cisterns, channels, etc.)</li><li>• Reservoirs, detention parks, and ponds</li></ul>	<ul style="list-style-type: none"><li>• River Erosion Control: Technical Standards for Maintenance</li><li>• River Management Facilities such as Levees and Inspection Method for River Channels</li><li>• Detailed Inspection Method for Embankments around Structures such as Gutters</li><li>• River Management Facilities such as Levees of Medium and Small Rivers and Inspection Methods for Riverways</li><li>• River Levee Qualitative Maintenance Technology Guidelines (plan), 2014</li><li>• River Levee Monitoring Technology Guidelines (plan)</li><li>• Inspection and Evaluation Procedures for River Management Facilities</li><li>• Levee and Revetment Inspection Results Evaluation Procedure (draft)</li><li>• Sluiceway/Gutter Tube Inspection Results Evaluation Procedure: River Edition (draft)</li></ul>	MLIT <sup>4</sup>
Surface water flood 	<b>Sewerage facility:</b> <ul style="list-style-type: none"><li>• Underground stormwater management facilities (cisterns, channels, drainage pipes, culverts, etc.)</li><li>• Stormwater detention ponds, parks, and gardens</li><li>• Sewerage treatment facility improvement</li></ul>	<ul style="list-style-type: none"><li>• Guidelines for Selecting PPP / PFI Methods in Sewerage Projects</li><li>• Guidelines for Draft Stormwater Management Comprehensive Plan</li><li>• Guidelines for Implementing Stock Management of Sewerage Projects</li><li>• Handbook on Formulating Sewerage Life Extension Plan Based on Stock Management Method</li><li>• Comprehensive Private Consignment Introduction Guidelines for Sewerage Pipeline Facility Management Work</li><li>• Maintenance Management of Sewage Sludge Treatment in Tokyo Metropolitan Government</li><li>• Sewerage Pipeline Facility Maintenance Manual</li></ul>	<ul style="list-style-type: none"><li>• MLIT<sup>5</sup></li><li>• MLIT<sup>6</sup></li><li>• MLIT<sup>7</sup></li><li>• MLIT<sup>8</sup></li><li>• MLIT<sup>9</sup></li><li>• Private company<sup>10</sup></li><li>• Public Interest Incorporated Association<sup>11</sup></li></ul>
Storm surge flood 	<b>Stormwater storage and infiltration facilities,</b> including: <ul style="list-style-type: none"><li>• Rainwater harvesting systems (collection systems and storage tanks installed in public, commercial, community buildings)</li><li>• Enhancement of infiltration surface (green spaces, pervious pavers and infiltration trenches, etc.)</li></ul>	<ul style="list-style-type: none"><li>• Guidance on Promoting Development of Stormwater Infiltration Facilities (draft)</li><li>• Technical Guidelines for Stormwater Storage and Infiltration Facilities of Tokyo Metropolitan Government</li><li>• Technical Guidelines for the Installation of Temporary Storage Facilities, etc. in Public Facilities of Tokyo Metropolitan Government</li><li>• Technical Guidelines for Stormwater Infiltration Facilities, Structure, Construction, and Maintenance Management (draft)</li><li>• River Storage Facilities etc. Technical Guidelines (draft)</li><li>• Manual on Stormwater Retention and Infiltration Facilities Installation in Detached Houses</li></ul>	<ul style="list-style-type: none"><li>• MLIT<sup>12</sup></li><li>• TMG and local municipalities<sup>13</sup></li><li>• TMG, Bureau of Urban Development<sup>14</sup></li><li>• Public Interest Incorporated Association<sup>15</sup></li></ul>

Source: Based on MLIT (2013). Note: MLIT = Ministry of Land, Infrastructure, Transport and Tourism; PPP = public-private partnership; PFI = private finance initiative.

### 3.2 Monitoring and Management Plans

Monitoring and management plans (or business plans developed by facility owners) take the overall technical and/or national guidelines and manuals for the various types of flood risk management investments one step further, and define the necessary actions (as well as guidelines regarding their frequency, management, and evaluation), standards, schedules, financial and human resource plans, etc. to carry out the O&M and management actions at each investment project level. These plans are often complemented by a stock/asset database, where the data and information linked to the performance indicators are recorded over time.

For example, TMG has been developing a **Five-year Sewerage Business Plan** since 2007. As in previous plans, the latest 2016–20 plan outlines TMG’s comprehensive strategy to implement a sewerage service that enhances resilience against disasters, improves water and environmental quality, and provides high-quality sewerage services cost-effectively through improved O&M. The plan: (i) establishes a holistic framework for envisioning the entire process up front, taking into account the limited time and financial resources; (ii) clarifies priorities in terms of what actions (inspection, repair, or reconstruction) are to be taken where and when; (iii) combines the work with surface water flood mitigation measures; and (iv) utilizes innovative technologies to expedite the process with minimal impact on the surrounding urban setting.

### 3.3 Stakeholder Collaboration and Engagement

The following sections will introduce examples of the sharing of roles, responsibilities, and financing for the O&M of IUFRM investments between the public sector, the private sector, and citizens and the community. By diversifying the stakeholders involved in the O&M of investments, sources of financial and human resources for O&M can be expanded, lessening the large burden that has been traditionally carried by the public sector, as well as enhancing the skill sets and approaches applied to O&M, and thus the value of urban flood risk management investments.

As described in **Knowledge Note 3, multipurpose, multifunction facilities and projects that integrate flood management as part of urban development, environmental conservation, or other public service efforts, are more conducive to the engagement of various stakeholders for O&M than single-purpose flood management measures.** For example, in flood detention facilities developed together with a large urban redevelopment initiative, the O&M of the entire facility, including for flood management, may be delegated to the private facility manager, while the public sector may incentivize or lessen the manager’s financial burden by easing regulations, etc.

**Through effective coordination and advance planning, stakeholders can implement low-cost solutions,** such as putting responsibility for O&M into the hands of community members if no advance expertise is required. For example, for a number of years, volunteer activities such as river cleanup by local communities or corporations have been integrated into formal national river maintenance measures (MLIT n.d.[c]). Also, academia can contribute to O&M efforts by studying and developing related technologies as well as providing technical inputs for manuals and advice on O&M implementation, as illustrated in **box 1.**

Sufficient resources (both financial and human) are required to execute periodic, sustainable, and efficient O&M. Cost-effective O&M, in turn, helps ensure that IUFRM investments are sustainable. The following sections describe common mechanisms for sharing costs and responsibilities between the public and private sector, as well as communities.

<sup>4</sup> For more details, see <http://www.mlit.go.jp/river/kasen/main/maintenance/index.html>.

<sup>5</sup> For more details, see <http://www.mlit.go.jp/common/001170811.pdf>.

<sup>6</sup> For more details, see [http://www.mlit.go.jp/mizukokudo/sewerage/mizukokudo\\_sewerage Tk\\_000433.html](http://www.mlit.go.jp/mizukokudo/sewerage/mizukokudo_sewerage Tk_000433.html).

<sup>7</sup> For more details, see [http://www.mlit.go.jp/river/suibou/pdf/gesui\\_stockmanagement\\_guideline2015.pdf](http://www.mlit.go.jp/river/suibou/pdf/gesui_stockmanagement_guideline2015.pdf).

<sup>8</sup> For more details, see <http://www.mlit.go.jp/common/001012691.pdf>.

<sup>9</sup> For more details, see <https://www.mlit.go.jp/common/001043219.pdf>.

<sup>10</sup> For more details, see <http://www.tgs-sw.co.jp/business/service/c01/c01/#t01>.

<sup>11</sup> For more details, see <https://www.jascoma.com/doc/book/list/gijutu-h1905.html>.

<sup>12</sup> For more details, see <http://www.mlit.go.jp/common/000113727.pdf>.

<sup>13</sup> For more details, see <http://www.tokyo-sougou-chisui.jp/shishin/shishin.pdf>.

<sup>14</sup> For more details, see <http://www.tokyo-sougou-chisui.jp/shishin/GijutuShishin.pdf>.

<sup>15</sup> For more details, see <https://arsit.or.jp/book14>, <https://arsit.or.jp/book13> and <http://arsit.or.jp/wp/img/book/kodate.pdf>.

<sup>16</sup> For more details, see [http://www.maff.go.jp/j/nousin/bousai/kaigan/ijikanri\\_manual\\_iinkai/pdf/manual\\_main-1.pdf](http://www.maff.go.jp/j/nousin/bousai/kaigan/ijikanri_manual_iinkai/pdf/manual_main-1.pdf).

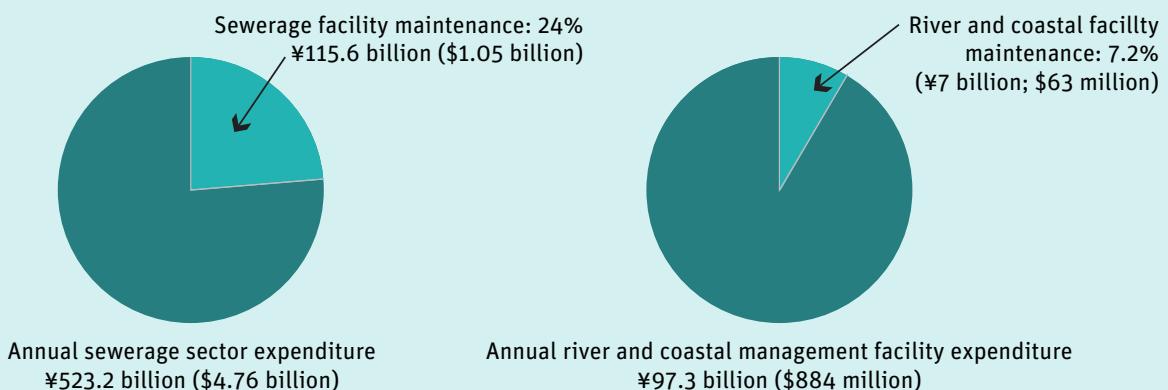
## Sharing O&M Costs and Responsibilities with the Public Sector

**Public sector stakeholders, including the national, provincial, and local governments, can coordinate vertically and horizontally to combine their strengths and unique roles across jurisdictions to enhance the effectiveness and efficiency of O&M.** An example of budgeting for O&M is included in box 2.

### Box 2: Budgeting for O&M: Financial Resources Allocated to the O&M of River and Sewerage Facilities in TMG

For operation and maintenance (O&M) to be efficient and sustainable, securing financial resources is a first step. In Japan, the required maintenance budget is integrated within annual budget allocations. For example, the Tokyo Metropolitan Government (TMG) in fiscal year (FY) 2016 allocated about ¥115.6 billion (\$1.05 billion) for sewerage facility maintenance, which accounted for 24 percent of its annual sewerage sector expenditure of ¥523.2 billion (\$4.76 billion). For the river and coastal management facility, TMG budgeted 7.2 percent (¥7 billion; \$63 million) of its total annual operational costs to O&M in FY 2016 (Bureau of Sewerage, TMG 2016a; Bureau of Construction, TMG 2016).

**Figure B2.1:** Financial Resources Allocated to the O&M of River and Sewerage Facilities, FY 2016



Source: Bureau of Sewerage, TMG 2016a; Bureau of Construction, TMG 2016.

**For example, at Tetsugakudo Park Collective Housing, the provincial and local (ward) governments worked together to enhance the efficiency of the O&M of stormwater detention facilities within a housing development initiative.** To counter the high costs of land and development, TMG extended the use of stormwater detention facilities by cooperating with the local governments of the Shinjuku and Nakano wards and UR, a semipublic housing development corporation, to reduce operation costs and improve land use. The four entities signed two agreements that combined their individual strengths and resources: TMG would fund the installation of a stormwater detention pond; the wards would maintain the parks for local residents; and the developer would address the residential development by constructing convenient amenities with a high profit potential. A stormwater detention facility was constructed below the collective housing building. The pilot<sup>17</sup> on the ground floor level of the building acted as an overflow area when the stormwater detention pond exceeded its capacity.

Most of the area covered by the O&M agreement is part of a watershed that has multiple land uses. The functions of the water reservoir and the park were funded by a cost-sharing agreement between TMG and the Nakano and Shinjuku wards, and an administrative agreement between the wards and UR. None of the four entities has property rights or exclusive use of the river. As per the administrative agreement, TMG and the two wards will take on the O&M of the stormwater detention pond and the park, respectively. UR will be responsible for the O&M of the piloti and the fence around it under normal circumstances.

<sup>17</sup> Piloti are a set of posts raising a building up from the ground.

However, it is clearly stated that after flooding, the two wards are responsible for removing debris and mud from the gutters and cleaning the fence. In addition, it is agreed that the designated administrator from the UR will activate the evacuation alarms in case of a disaster event.

### Sharing O&M Costs and Responsibilities with the Private Sector

**There are many opportunities to engage the private sector in financing and/or implementing the O&M of urban flood management investments.** In light of the increasing stock of aging infrastructure facilities, Japan is widely promoting the engagement of the private sector through PPPs and PFIs. Various types of arrangements for sharing responsibility for sewerage facilities are illustrated in **figure 4**.

**Figure 4:** Private Sector Participation in Sewerage Projects in Japan

Scope of Work	Direct Governance / Individual Outsourcing	Private Subcontracting	Design, Build, and Operate	Conventional PFI Method	Concession
Top-down execution					
Decision making and consensus building					Municipality
Establishment of plan			Municipality		
Collection of fee from the public		Municipality			
Securing financial source	Municipality				
Facility (design and construction)					Private Sector
Facility repair and renew				Private Sector	
Inspection and maintenance		Private Sector			
Operation					
Remarks	Implementing directly by the municipalities or subcontracting required services to the private sector.	Subcontracting services based on tenderer's performance and capability, with more than one-year contract.	Subcontracting design, building, and O&M as a package (financial source to be secured by the public sector).	Subcontracting design, building, and O&M as a package (financial source to be secured by the private sector).	Subcontracting the management right. Private sector to collect service fee from the public.
Typical contract period	1 year	3–5 years	15–20 years	Approximately 20 years	Approximately 20 years
Number of completed projects as of January 2018	-	450	25 (including ongoing cases)	11	1
Implemented cases	-	Kahoku City etc. Treatment plant and sewerage pipe's O&M	TMG etc. Project on recycling sewerage sludge	Yokohama City Project on recycling sewerage sludge	Hamamatsu City Treatment plant and pumping station's O&M and renovation

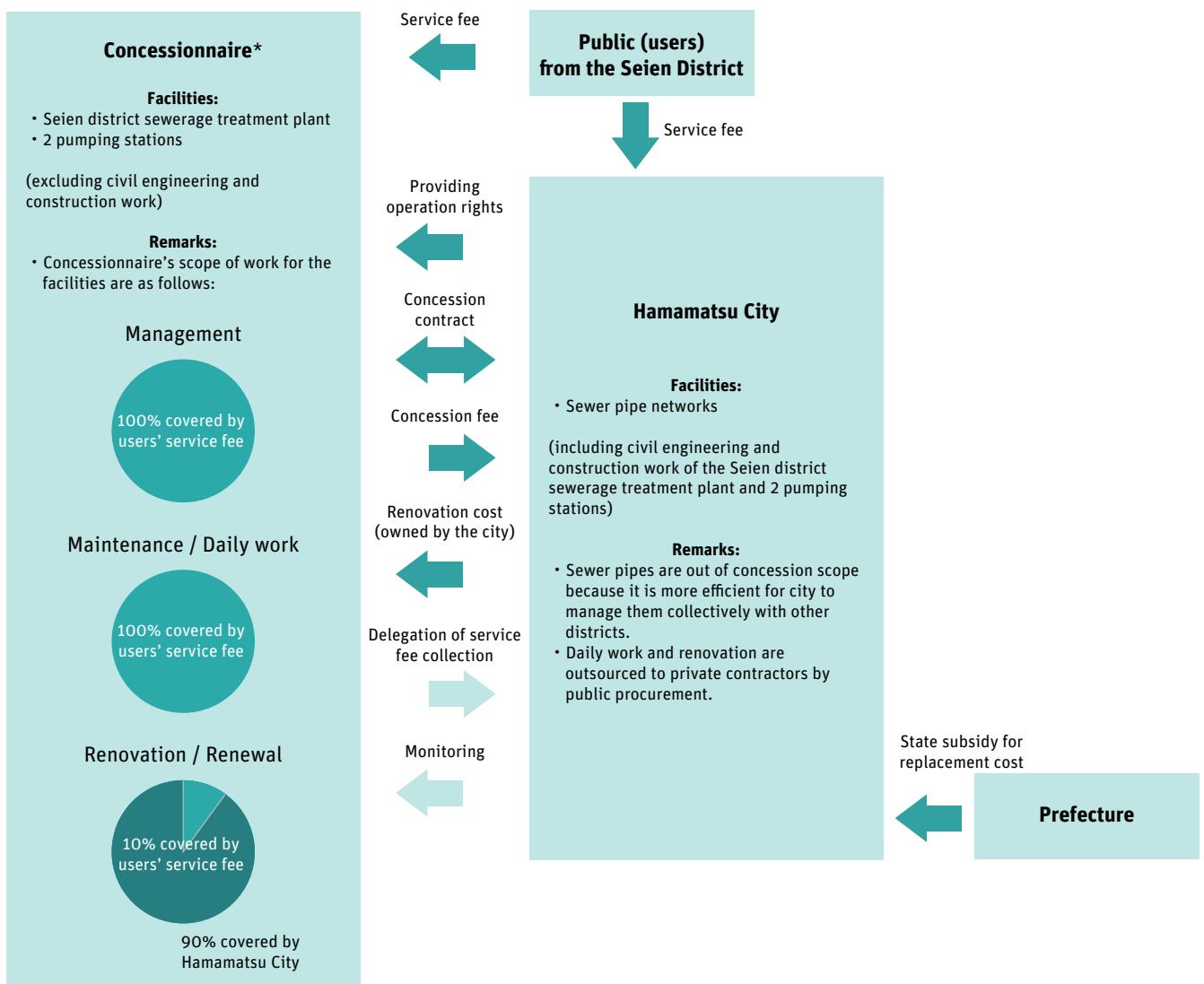
Source: MLIT n.d.(d).

Note: O&M = operation and maintenance; PFI = private financed initiative; TMG = Tokyo Metropolitan Government.

Several tools can be used to secure financial resources for the O&M of IUFRM investments. For example, the **Shibaura Wastewater Treatment Plant in Tokyo** was upgraded in 2015 to increase the underground water retention capacity of untreated stormwater and wastewater to 76,000 cubic meters ( $m^3$ ), and was funded through a PFI. The project became the first wastewater treatment facility to utilize a new regulatory framework called the Multi-Level City Planning System under the City Planning Act, which enabled “vertical urban planning” that allowed stakeholders to undertake redevelopment projects at multiple levels, regardless of the overlapping public urban facilities beneath or above them. The project in Shibaura comprised two public and private multilayered projects: (i) the underground public sector wastewater and stormwater treatment and detention facility; and (ii) the above-ground private sector commercial redevelopment of a 150 meter (m) high office building and park. TMG, the administrator of the sewerage system, owned a part of the office building in return for leasing the land on which the facility was constructed. Private enterprises paid ¥84.8 billion (\$725 million at the time of auction) for a fixed-term contract of 30 years. The revenues generated from leasing the office buildings allowed TMG to keep the sewerage utility fees low, subsidize the cost of repairing other sewerage facilities, and secure stable financial resources for O&M (Hashimoto 2015). (Further information on the Shibaura Wastewater Treatment Facility is included in the appendix, case 11.)

The redevelopment of the **Yokohama Station Tower** and **Excite Yokohama 22 District** is another example of cost and role sharing between the public and private sector. The initiative combines private urban development with the enhancement of stormwater management capacity in a 5,000 square meter ( $m^2$ ) area. MLIT, Yokohama City, and private developers are collaborating to build the Yokohama Station Tower, a flagship project that is expected to be completed in 2020. As part of this initiative, a stormwater detention cistern with a 170  $m^3$  capacity is under construction below the basement level 3 of a mixed-use 26-story building (Climate Change Adaptation Information Platform 2018). A new national policy, designating the area around Yokohama Station as the first “Flood Mitigation Focus Area” in Japan, was implemented under the revised National Sewerage Law (updated in 2015), which promotes the installation of stormwater storage facilities in large-scale private redevelopment projects through PPPs. The private sector developers conduct O&M of the facilities, but also receive subsidies for the work they do (e.g., for construction of an underground cistern) from the national and local governments (Tanigawa 2017; MLIT 2016a). For this project, private developers paid one-third of the total installation cost, with the remaining two-thirds being subsidized by the national government and Yokohama City (one-third each). In addition to the subsidies, other incentives included a tax reduction for installing a larger storage capacity (300  $m^3$  or more; Ishii 2019). (Further details on the Yokohama Station Tower and Excite Yokohama 22 District are included in the appendix, case 8.)

Many new mechanisms and approaches for engaging the private sector in resilient water management are being explored and trialed in Japan, particularly since the Act on Promotion of Private Finance Initiatives (PFI Act) was updated in 2011. For example, **Hamamatsu City** implemented the first concession project in Japan where the private concessionaire manages and leads the daily O&M and renovation work of, in this case, two pumping stations. The concessionaire has agreed to provide cost-effective sewerage services for a 20-year period, while the city retains responsibility for fee collection and the O&M of sewerage pipes. As a result of this partial concession, cost savings of approximately ¥8.6 billion are expected over the 20 years, including ¥2.5 billion to be paid to Hamamatsu City as concession fees (Suzuki 2019).

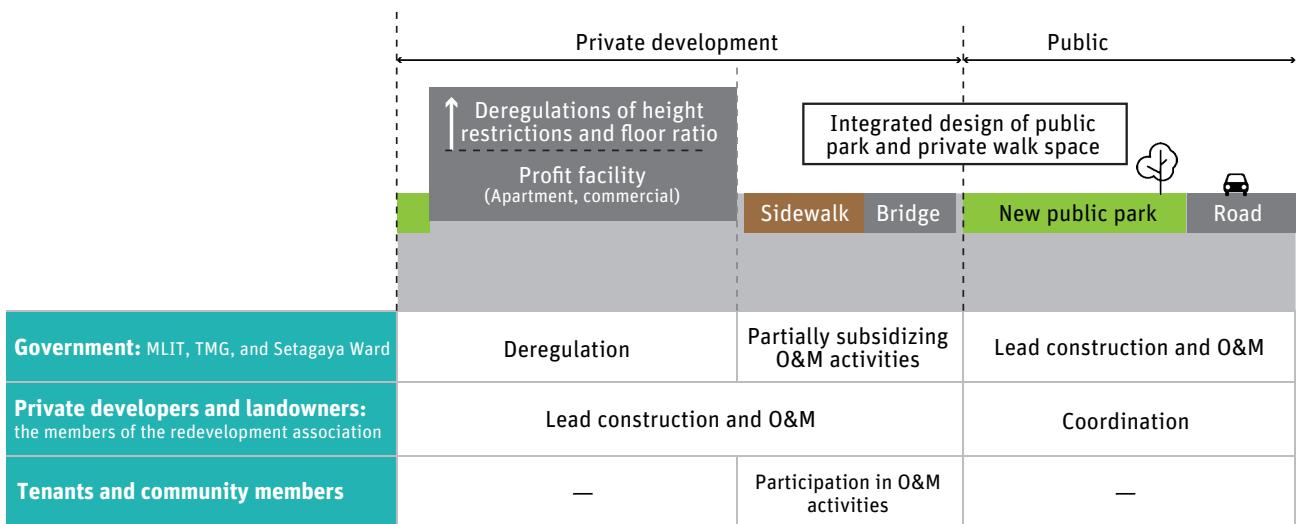
**Figure 5:** Concession Project Scheme for Hamamatsu City's Sewerage System

\* Hamamatsu Water Symphony Co., Ltd.  
established by six companies, including Veolia Japan.

Source: Suzuki 2019.

New developments that integrate green infrastructure and water-sensitive design are also being managed through PPP schemes. For example, the **Futakotamagawa Rise and Futakotamagawa Park** project (discussed in the appendix, case 2) integrates various green infrastructure features; the rise development is led by the private developer, and the park's development is led by the city. As described in **figure 6**, the O&M of the green infrastructure within the Futakotamagawa Rise complex is managed by the company, tenants, and citizens, while the O&M of the new public park is led by the local government. However, using a collaborative approach, the O&M of the entire area involves various private and citizen's educational programs and activities (such as park cleaning, etc.).

**Figure 6:** Sharing Responsibility for the Development and O&M of the Futakotamagawa Rise and Futakotamagawa Park Project



Source: Development Bank of Japan 2019.

Note: MLIT = Ministry of Land, Infrastructure, Transport and Tourism; O&M = operation and maintenance; TMG = Tokyo Metropolitan Government.

Similarly, **Tokyo Skytree Town** was developed by the privately owned Tobu Railway Company. Objectives included constructing a new broadcasting tower, along with promoting the urban renewal of the surrounding neighborhood. Most of Sumida Ward, where the tower is located, is below sea level, making drainage and infiltration difficult. Therefore, the developer built a large stormwater storage tank with a runoff control capacity of 1,835 m<sup>3</sup> and a reuse storage capacity of 800 m<sup>3</sup>. This was the largest in the Tokyo metropolitan area at the time of its construction. Although Sumida Ward has a subsidy scheme for the reuse of stormwater, Tobu Railway Company chose not to use the subsidy and instead considered this an opportunity to fulfill its corporate social responsibility. Moreover, the company installed stormwater storage facilities with greater capacity than the minimum required and also took charge of their O&M. (Further information on Tokyo Skytree Town is included in the appendix, case 13.)

### Sharing O&M Costs and Responsibilities with Community Members

**O&M responsibilities can also be shared by citizens and communities through bottom-up approaches.** Role-sharing mechanisms include O&M agreements, community-based solutions that engage local residents, public subsidy programs for O&M, and area management. Examples from Sumida Ward (appendix, case 12) and Higashimurayama City (case 18) in Tokyo showcase bottom-up approaches to sustainable O&M.

In **Sumida Ward**, heavy rains have frequently caused surface water floods and inundation damage since the 1980s. In 1982, the ward kicked off its efforts to store and utilize rainwater by requesting the Japan Sumo Association to use rainwater at a local sumo stadium. Since Sumida Ward is located below sea level, stormwater infiltration is not effective in the area. Instead, a stormwater storage facility was adopted as the main stormwater runoff control measure. Given the fact that the ward's residential areas are widely dispersed, the installation of rainwater storage facilities would involve significant costs. Thus, it was necessary to seek ways to reduce the costs of installation and O&M as well as to promote public awareness of and cooperation with the ward's policy.

To control stormwater runoff in the ward, residents have been voluntarily installing rainwater storage tanks as well as small storage tanks at their homes. Further, Rojisons, or community-based rainwater storage and utilization facilities, were established in 1988 for the purpose of emergency water supply as well as urban flood risk management. As of 2008, there were 21 Rojisons installed in the ward. The rainwater collected from the roofs of residential buildings is stored in an underground tank, and residents can pump out the stored rainwater with a hand pump for washing streets and watering trees. The ward provides subsidies so that citizens can install Rojisons at a lower cost, and the O&M of rainwater storage tanks is conducted by citizens and local communities.

This reduces the ward's cost and time for O&M. Rainwater storage tanks installed at residences are visible from the street, which promotes better public awareness of flood risk management. Stormwater storage is promoted by considering how to utilize the stored water. (Further information on Sumida Ward is included in the appendix, case 12.)

Hagiyama Shikinomori Park shows how the TMG subsidy program is adopted for supporting green conservation and alleviating the O&M cost of stormwater runoff control facilities. The Privately Developed Park Program, established in 2006 (Bureau of Urban Development, TMG 2006), enables the private sector to develop a park without public finances by deregulating building codes and providing tax waivers for landowners. (Property taxes are waived for 10 years and inheritance taxes are reduced by 40 percent if the land is lent for 20 years or longer.) The program allows business operators to develop high-rise apartment complexes in areas that are otherwise designated for parks and green spaces if they meet certain conditions.

Hagiyama Shikinomori Park was the first beneficiary of the program. The total site area was 1.5 ha, 70 percent of which (1 ha) was developed as a park and the rest as apartment complexes that contained 184 apartment units, which were as high as 34–35 m with 11 stories. The site's land right is owned by an apartment management association, which pays a monthly fee of ¥250,000 (roughly \$2,200), or ¥1,400 (\$12.30) per apartment unit as the park maintenance fee. In return for opening the park to the public, the apartment complex management company does not have to pay property or urban planning taxes. The private sector supervises the park area and is responsible for its O&M as part of a 35-year contract with the apartment management association; TMG is responsible only for the O&M of the public restrooms (Real Estate Baseball Association 2009). This arrangement reduces the public sector's O&M burden (further information on Hagiyama Shikinomori Park is included in the appendix, case 18).

### 3.4 Innovative O&M Technologies

In Japan, the private sector is innovating O&M technologies to design and construct flood risk management investments. Adopting advanced technologies and innovative business models not only makes O&M simpler and more efficient but also improves the capacity and the effectiveness of flood risk management throughout the life cycle of an IUFRM investment. It also enables O&M to be managed by a third party, such as a local public entity or private sector organization, which helps reduce the burden of O&M management. Investment designs can incorporate innovative technology to reduce the lifetime costs and/or human resources needed for O&M.

For example, Japan has developed a new **rehabilitation method for sewer pipes** that puts materials made from vinyl chloride around the inside of the pipes. This method allows construction without digging up roads and interrupting traffic on the ground, while reducing costs and construction time, and also allows the continual flow of wastewater. Moreover, this reinforcement makes the sewer pipes more resilient to earthquakes. Thirteen countries in Europe, North America, and Asia, including Germany, Singapore, and the Republic of Korea, have already implemented this solution while renovating their aging sewer pipes. The projects cover a combined total of approximately 111 km of pipes. A box culvert (1,670 mm wide x 1,500 mm high x 30 m long) can reduce O&M costs by approximately 35 percent, compared with other traditional methods such as pipe lining. (Further information on Tokyo Central Wards' O&M of sewerage facilities is included in the appendix, case 16.)

Furthermore, the Government of Japan is leading various initiatives to utilize advanced technology and data to improve the efficiency and effectiveness of aging infrastructure stock, including but not limited to flood management investments. Table 4 summarizes the phases in which the application of advanced technology and data management systems in the field of maintenance and management are being conceptualized and advanced in Japan.

An online MLIT platform<sup>18</sup> serves as an information hub for O&M updates and good practices, new technologies, etc. for various types of public infrastructure (including river, sewer, and coastal infrastructure) relevant to urban floods. Annual infrastructure maintenance awards are also announced and shared through the platform, which is an important channel for sharing and advancing innovative O&M solutions. Some awards have been for the utilization

<sup>18</sup> See <http://www.mlit.go.jp/sogoseisaku/maintenance/index.html>.

of Internet of Things (IOT) sensors or drones for the inspection and monitoring of sewerage pipes, led by municipal sewage departments (MLIT 2018b). Research and development to further develop and scale such initiatives are ongoing, and several are expected to be tested and applied in the near future.

**Table 3:** Utilization of Advanced Technology and Data in the Field of Maintenance and Management in Japan

	Type of Advanced Technology for Enhancing Infrastructure Operation and Maintenance (O&M)	Planned/Ongoing Application through National-Level Initiatives
Planning	Utilization of big data to analyze and model infrastructure conditions across time, develop an O&M plan, and ensure prioritization.	Development of infrastructure data platform.
Monitoring and inspection	Utilization of robots, drones, tablets, and artificial intelligence (AI) to enhance the efficiency of monitoring and inspection work; automatic and real-time monitoring through sensor technologies, etc.	Inspection and/or prescreening through utilization of robots and drones, sensors, and AI; real-time monitoring and recording of data through tablets and mobile devices.
Maintenance, repairs, and replacement phases	Utilization of information and communications technology such as 3D data to enhance efficiency and prioritization of maintenance, repair, and replacement work.	The use of drones for surveying and construction, and of Building Information Modeling (BIM), City Information Modeling (CIM) methods to make 3D information on infrastructure available.

*Source:* MLIT 2018a.

## 4. Lessons Learned and Key Takeaways

Japan's efforts to sustainably operate and maintain IUFRM investments, as illustrated in the cases reviewed here, provide the following key lessons and takeaways.

**The function of IUFRM investments can be effective only when the O&M of these facilities is carried out adequately.** O&M is thus a crucial component of well-designed IUFRM investments, and enhances (i) ease of updating and adaptation; (ii) cost-effectiveness (by decreasing life-cycle costs); (iii) effectiveness of governance and coordination mechanisms; (iv) use of innovative, appropriate technology and business models; and (v) engagement of citizens and other stakeholders through participation, consensus, and ownership.

**Executing efficient O&M through preventive maintenance and asset management can reduce life-cycle costs.** Effective institutional framework and coordination mechanisms include signed agreements between each stakeholder and related organization. Innovative, appropriate technology and business models not only make O&M easy and efficient, but also enhance and sustain the effects and functions of IUFRM. Bottom-up, low-cost solutions that feature the participation of community members can make O&M more efficient.

**An integrated approach is key.** For large-scale IUFRM investments (such as river embankments) with high O&M costs, a top-down approach led by the national or local government is necessary. But this can be complemented by a bottom-up approach featuring the participation of local residents and community members, who can, for example, help to maintain stormwater storage and infiltration facilities.

**Engage stakeholders.** The goal of IUFRM to reduce flood risks and damage in urban areas is shared among urban public bodies, the private sector, communities, and citizens. Every stakeholder needs to recognize the importance of O&M and help secure the required budgetary and human resources. IUFRM investments with multiple benefits, including commercial and recreational uses, can help to encourage stakeholders' involvement.

**Provide incentives for private sector engagement.** The private sector may be encouraged to participate where IUFRM measures are implemented in combination with private projects such as large-scale land development and urban redevelopment. Private developers may be expected to proactively undertake the O&M of the IUFRM facilities they install to showcase their capability. Experience from Japanese cities indicates that incentives may include publicly driven policy mechanisms such as easing regulations on floor area quotas (as in Futakotamagawa Rise and Futakotamagawa Park) or requiring a certain level of stormwater management in exchange for subsidies (as in Yokohama Station Tower and Excite Yokohama 22 District). Meanwhile, private developers may see that water-sensitive urban design efforts can enhance their image within society (e.g., Tokyo Skytree Town). Ensuring an array of options for private sector involvement in the O&M of IUFRM projects is crucial.

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## **UFCOP**

Urban Floods Community of Practice is an umbrella program to share operational and technical experience and solutions for advancing an integrated approach to urban flood risk management, and leveraging expertise and knowledge of different stakeholders and practice groups and across the WBG. The program supports the development of an interactive space for collaboration and exchange on the subject, facilitating users' access to information and adaptation of knowledge to local conditions, and bringing together different stakeholders to enhance collective knowledge on integrated urban flood risk management.

## **World Bank Tokyo DRM Hub**

The World Bank Tokyo Disaster Risk Management (DRM) Hub supports developing countries to mainstream DRM in national development planning and investment programs. As part of the Global Facility for Disaster Reduction and Recovery, the DRM Hub provides technical assistance grants and connects Japanese and global DRM expertise and solutions with World Bank teams and government officials. The DRM Hub was established in 2014 through the Japan-World Bank Program for Mainstreaming DRM in Developing Countries—a partnership between Japan's Ministry of Finance and the World Bank.

## **GFDRR**

The Global Facility for Disaster Reduction and Recovery (GFDRR) is a global partnership that helps developing countries better understand and reduce their vulnerabilities to natural hazards and adapt to climate change. Working with over 400 local, national, regional, and international partners, GFDRR provides grant financing, technical assistance, training, and knowledge sharing activities to mainstream disaster and climate risk management in policies and strategies. Managed by the World Bank, GFDRR is supported by 36 countries and 10 international organizations.

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