Learning from Japan’ s Experience in Integrated Urban Flood Risk Management:

A Series of Knowledge Notes

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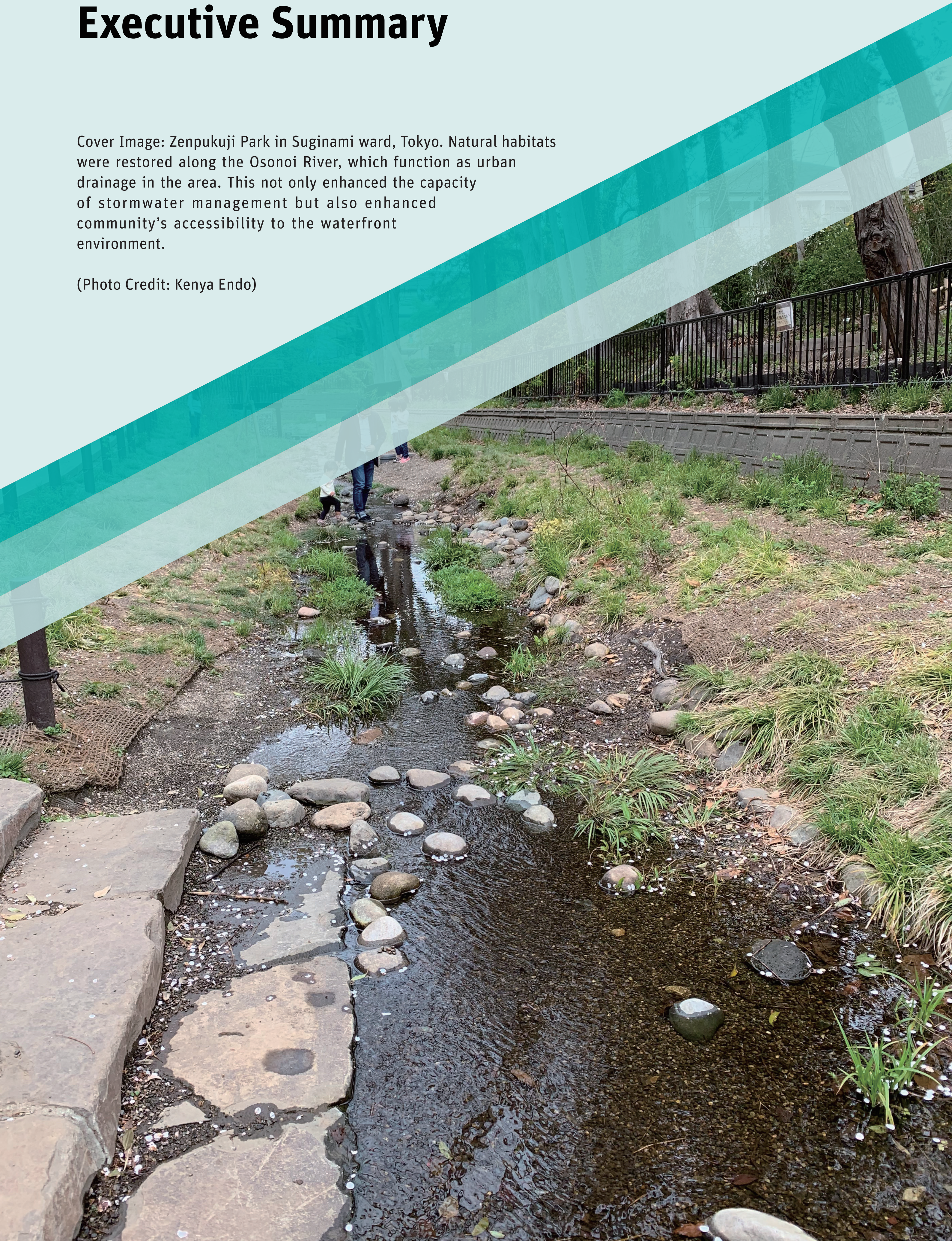
Executive Summary



Cover Image: Zenpukuji Park in Suginami ward, Tokyo. Natural habitats were restored along the Osonoi River, which function as urban drainage in the area. This not only enhanced the capacity of stormwater management but also enhanced community's accessibility to the waterfront environment.

(Photo Credit: Kenya Endo)

Globally, floods are the most frequent and damaging natural hazard. Between 1998-2017, floods led to economic damages exceeding US$600 billion, affected more than 2 billion people, and resulted in around 142,000 fatalities[1]. Compounded by rapid urbanization and climate change, these losses will likely increase, especially in developing countries where populations are rapidly growing in flood-risk zones. This poses a serious development challenge to many countries and their efforts to reduce poverty and increase shared prosperity. To help manage the impact of floods on people and economies, the World Bank provides technical assistance, advisory services, and financial support to a range of countries and cities around the world.

Facing different types and combinations of flood risk, Japan's rich history, range of investments and approaches taken offers a unique knowledge opportunity for other countries seeking to adopt and advance integrated urban flood risk management (IUFRM). Japan is world-known for its culture of 'disaster resilience'. Japan has experienced many major disasters, and has a history of developing technologies, policies, and practices that help to mitigate disaster impacts. Many major Japanese cities, including Tokyo, are located in flood-prone lowland areas. Japan's strategies for reducing flood risk span four decades, from the 1979 implementation of comprehensive flood risk management measures along 17 rivers to recent plans to mitigate the effects of heavy rain across many urban areas. Japan's experience can support other countries as they develop their own flood risk management programs.

This series of knowledge notes compiles many of the key lessons learned from Japan's IUFRM efforts. While any strategy to reduce disaster risk must be developed based on a close understanding of local contexts, the aim of this series is to help members of the international community improve their own approaches to managing urban floods. These notes are not intended to provide a comprehensive analysis but rather a snapshot highlighting key aspects, practice and lessons learnt from Japanese practice. The four knowledge notes in this series cover urban floods from assessment and planning through to implementation and maintenance, in the following order:

1. Urban Flood Risk Assessment and Risk Communication
2. Urban Flood Risk Reduction Investment Planning and Prioritization
3. Designing and Implementing Urban Flood Risk Management Investments
4. Ensuring Sustainability through Operations and Maintenance

The IUFRM approach taken in Japan focuses on all sources of flooding, and balances structural and nonstructural management techniques according to stakeholder goals and environmental contexts. Several aspects of this definition are key. An integrated approach includes stakeholders from various sectors who work across institutional boundaries to achieve common goals. This is especially important given that watersheds and flood plains rarely coincide with political jurisdictions. Urban flood management should be designed for the unique characteristics of a given context, including demographics, natural and the built environment, central and local governing structures, and communities to serve. That said, there are some common best practices that may be translated across locations.

Importantly, IUFRM considers multiple types of floods that may occur singly or in combination: river floods, surface water floods, and storm surge floods. Many cities face a combination of these risk types, and flood events can include multiple sources as well. In order to mitigate the damage caused by these floods, authorities must draw on a toolkit of both structural and nonstructural measures.

The four knowledge notes draw on and are complimented by an appendix of over 20 detailed flood management case studies from across Japan. They range from risk assessments used to create neighborhood-level evacuation plans in five adjoining wards in Tokyo (Knowledge Note 1, box 5) to Japan's first housing development to apply an infiltration-based construction method (Akishima Tsutsujigaoka Collective Housing, appendix, case 17). Examples were selected by a committee comprised of Japanese technical experts from national and local governments, academia, the private sector, and civil society organizations. The committee ensured that evidence-based examples of IUFRM measures for various types of flood risk were highlighted, so as to draw out good practices and lessons useful to developing countries. Each case analyzes a specific IUFRM strategy and supports the discussion of various components of IUFRM in the knowledge notes.

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1 Source: Wallemarq, P., Below, R., & McLean, D. (2018). UNISDR and CRED report: Economic Losses, Poverty & Disasters (1998–2017).

1. Knowledge Note 1: Assessing and Communicating Urban Flood Risk

In order to prepare for urban floods, cities must first understand the types and extent of flooding they are likely to face. The IUFRM process in Japan starts with assessing risk and then communicating results to local populations. Assessments are used to inform risk management strategies that may be structural (i.e., embankments, nature-based systems) or nonstructural (i.e., preparedness, land use plans, evacuation plans). The first knowledge note in this series outlines Japan's methods of risk assessment, and strategies used to disseminate the results to various stakeholders.

Due to the complexity and diversity of urban flood risks, assessment approaches must be selected based on flood type and the urban and geographical characteristics of the area: different types of flooding are assessed in different ways. Risk assessments are built from a variety of data sources, including historical flood surveys, hazard analyses, land use surveys, and flood vulnerability assessments of structures and facilities. Today, climate change must also be included in flood risk assessments. In Japan, cities face increasingly extreme and unpredictable hazard events, so stakeholders are planning for greater levels of risk than ever before. Once completed and validated, the information generated by risk assessments must be effectively communicated to various stakeholders and decision makers who determine how to invest in flood risk reduction, preparedness, and evacuation measures.

There is no one-size-fits-all approach to assessing and communicating urban flood risk. Planners need to carefully consider their objectives and audience. Through trial and error, Japan has accumulated know-how regarding a variety of approaches that prepare stakeholders to take timely, effective actions to manage and mitigate urban flood risk. This knowledge is increasingly important as floods become more extreme. Communication strategies such as hazard maps, warning systems, and evacuation plans are essential to helping people get out of harm's way when an unprecedented flood event occurs.

2. Knowledge Note 2: Planning and Prioritizing Urban Flood Risk Management Investments

Once flood risk is understood, the next step for cities is to determine the most effective ways to reduce that risk. The second knowledge note examines how Japan uses urban flood risk assessments to develop investment strategies for structural and nonstructural measures. Prioritization of flood management measures is based on criteria including the probable frequency and strength of floods, potential damage to people and property, cost-benefit analyses, social and environmental assessments, and the capacity of existing flood risk management measures. This knowledge note focuses on the practical experience of the Tokyo Metropolitan Government, Shiga Prefecture, and Setagaya Ward.

In Japan, flood risk planning at the local government level generally follows a three-step process. First, the city establishes unified goals for flood mitigation. The vision coordinates information gathered from risk assessments with factors including local characteristics, past disasters, as well as larger national government strategies. Second, a citywide operational framework is established, outlining flood risk management targets for each relevant sector (e.g., rivers, sewerage). These targets are set based on city development policies, coordination with other departments, availability of financial resources, and technical feasibility analysis (i.e. land availability). Third, consensus-building and responsibility-sharing enable agreement surrounding the implementation of the shared IUFRM goals.

IUFRM is based on collaboration and role sharing among various sectors and stakeholders. Stakeholders such as national and local governments, the private sector, citizens, and the academia work together to set and achieve shared goals for mitigating the risks and damages of urban floods. Plans for city-level flood management in Japan are formulated and implemented by departments responsible for sewerage and drainage, watersheds, urban development, the environment, river management, and disaster risk management. Japan's national government, especially the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), plays a critical role in supporting local governments throughout the planning and prioritization process. Since many local governments typically do not have sufficient technical and financial resources to implement effective flood management measures on their own, the national government helps identify similarities across regions and facilitate collective, consistent, and effective approaches to resolving urban flood risk management challenges. Cities in Japan also actively engage stakeholders from the private sector and local communities in the planning and prioritization process to fill gaps that the public sector cannot manage on its own.

3. Knowledge Note 3: Designing and Implementing Urban Flood Risk Management Investments

Following the planning and prioritization stage, urban flood management strategies must be implemented smartly in order to be effective. This third knowledge note examines key elements of good design," for IUFRM investments based on Japan's experience. It showcases several types of IUFRM projects implemented in Japanese cities, the factors used to select and design specific measures, and the methods used to enhance their effectiveness and sustainability. The connection between risk assessments, planning (discussed in the first two knowledge notes), and implementation is examined through case studies organized by flood type (river, surface water, storm surge, and multihazard). Cases include both structural (including nature-based solutions) and nonstructural measures (and further details of these cases are included in the appendix).

Japanese experience in designing and implementing IUFRM offers several key takeaways. For example, it is essential to select measures based on context, and to consider the strengths and weaknesses of each IUFRM measure. Stakeholders should also ensure that responsible entities receive the technical support needed for successful implementation. Wherever possible, measures should be multifunctional, and not only manage flood risks but also provide other benefits such as green space or public facility upgrades. Measures that integrate green and gray infrastructure can serve multiple purposes, and therefore increase the overall value of the investment. Community and private sector engagement can help to identify opportunities to generate multiple benefits, and may also help reduce life-cycle costs. Finally, in any IUFRM measure it is necessary to design and implement clear governance mechanisms delineating roles and responsibilities for design, construction, and operation and maintenance (O&M). While these lessons are derived from an analysis of Japanese projects and experiences, they provide a useful starting point for any IUFRM project.

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

The success of IUFRM investments relies on sustained O&M throughout the design period and beyond. The fourth knowledge note examines how Japan is managing the O&M of IUFRM investments. Effective O&M depends on the technical knowledge, skills, and capacities of the staff responsible for managing related measures. O&M can only be effective if there are sufficient long-term resources as well as policy and institutional frameworks to monitor and evaluate these measures.

Japan today is faced with aging infrastructure, much of it in need of repair or replacement, and is also contending with an aging and shrinking population. As the workforce declines, obtaining the financial and human resources necessary for O&M is increasingly difficult. These limitations are driving experimentation with new approaches to O&M. The Japanese experience highlights two key elements of sustainable O&M: regular performance monitoring and evaluation; and regular inspection, maintenance, repair, and replacement work. In order to carry out these tasks, stakeholders need to develop plans and standard operating procedures outlining the frequency of O&M tasks, provide personnel with relevant skills and knowledge, and acquire the financial resources needed to conduct the necessary activities. In some cases, construction of flood risk management measures can be combined with private real estate development opportunities, allowing O&M to be led by private firms motivated by development incentives. In others, low-cost solutions that depend on community volunteers may be the best option. Leveraging the interest of both the private sector and local communities can insulate strained municipal government budgets from the financial burden of O&M. Japan's experience suggests a number of good O&M practices, including the development of technical guidelines, monitoring plans, public-private partnerships, the utilization of new technologies, and the engagement of citizens. Overall, finding O&M strategies that work within local needs and limitations ensures the delivery of effective flood management over the long term.

Knowledge Note 1: Assessing and Communicating Urban Flood Risk

Cover Image: Shiga Prefecture's Disaster Information Map accessed from a smart phone. The map disseminates information on various natural disaster risks, including of floods, landslides, and earthquakes. The platform is used to enhance disaster risk awareness, preparedness, and evacuation and as a key urban flood risk management strategy.

(Shiga Prefecture. n.d.[a])

1. Summary

Understanding the causes of flood disasters, and ways to mitigate them, is an essential first step toward the integrated management of flood risk in cities. This can help decision makers guide investments out of hazardous zones, save lives and property, as well as ensure that investments take into account both expected and unprecedented disaster events. Careful disaster planning is critical in complex urban environments that are home to large populations as well as multiple infrastructure and service networks. Though risk assessments are of various types, depending on the needs and objectives of the stakeholders involved, all share the objective of enhancing the knowledge and management of risk. To this end, it is also important to consider how assessment results are communicated to stakeholders, as well as to the wider public.

In Japan, risk assessments are generally used to inform flood risk management plans and investments, as well as to communicate flood risk information to enhance preparedness and evacuation plans. This Knowledge Note examines the different types of urban flood risk, and the roles of specific sectors and stakeholders in conducting flood risk assessments in Japan. It provides an overview of the various objectives and methodologies used. Examples include risk assessments conducted to inform the design of structural flood management measures and the planning of nonstructural flood evacuation, as well as to raise community awareness and integrate climate change considerations in risk management efforts. These examples showcase how and why various risk assessments are conducted, and how they are used to enhance decisions and actions. The note also considers the effectiveness of risk communication measures in Japan, and analyzes the prevalent methods and technologies used to strengthen flood risk mitigation, preparedness, and evacuation plans in Japanese cities.

Key questions that may guide Japanese cities in understanding and assessing flood risk include the following:

- What types of flood risk affect urban areas?
- How can cities use information on the risks and impacts relevant to key sectors and stakeholders to enhance flood risk mitigation and preparedness?
- How can the potential risks of climate change be considered within the flood risk assessment process? How can cities deal with uncertainty?
- How can flood risk information be communicated in a timely and effective manner? How do communication content, means, and processes influence preparedness and response capacities, especially of citizens (and, specifically, vulnerable groups) and the private sector?

Japan's rich history and experience in managing urban flood risk offer the following lessons:

- **Consider the context.** The risks and impacts of urban floods are complex and diverse, depending on flood type and the geographical and other characteristics of urban areas. Different stakeholders are affected by floods in different ways. For this reason, Japan pursues several approaches to risk assessment and risk communication, with different purposes and different target users. Choosing the right approach requires a careful examination of the variables involved. Regardless of location, flood risks are assessed using simulations and analytical models. In Japan, river administrators, sewerage system administrators, and mayors of municipalities at risk of inundation are responsible for risk assessments.
- **Consider the purpose.** Risk assessments can serve many purposes, such as designing and examining flood control infrastructure, establishing and revising land use plans and standards, planning and developing evacuation methods, examining disaster insurance and financing methods, and considering climate change adaptation measures. The scope of the risk assessment must match its purpose.
- **Think ahead.** In light of climate change impacts, flood risk assessments should consider various scenarios to deal with climate uncertainty. Many cities in Japan face limitations in the information and resources needed to conduct their own climate change risk and impact assessments. Often, assessment results are too uncertain to support evidence-based decision making. However, urban planners across Japan see the need for and value of integrating climate change impacts within their flood risk assessment processes. Japan promotes ways to integrate climate change considerations into the risk assessments guiding both structural and nonstructural investments.
- **Work together.** At the central level, the Ministry of Land, Infrastructure, and Transport and Tourism (MLIT) formulates and revises laws and guidelines related to investment in the management of various types of flood risk (related to rivers, sewerage systems, watersheds, coastal protection, and disaster mitigation). As the

number of urban floods increases in Japan, many cities are stepping up their efforts to better understand, define, and implement their own assessments to inform city-level flood management policies and action plans, as well as to enhance preparedness and evacuation plans (such as by improving hazard maps). Additionally, the Government's Cabinet Office, which is the key coordinating agency for disaster risk management in Japan, monitors and reviews urban flood disasters and risk management measures on an annual basis, and updates relevant laws, policies, and institutional frameworks to ensure lessons learned are scaled through a coordinated approach. Scientific knowledge underpins the new policies and approaches, which were reviewed by researchers and academic experts. Regarding risk communication, local governments, in partnership with private sector and community members, are improving what, when, and how risk information is communicated by developing more targeted approaches. For example, efforts to improve the communication of flood risk to railway and metro operators in Japan can greatly enhance the capacity of their large passenger bases to effectively evacuate.

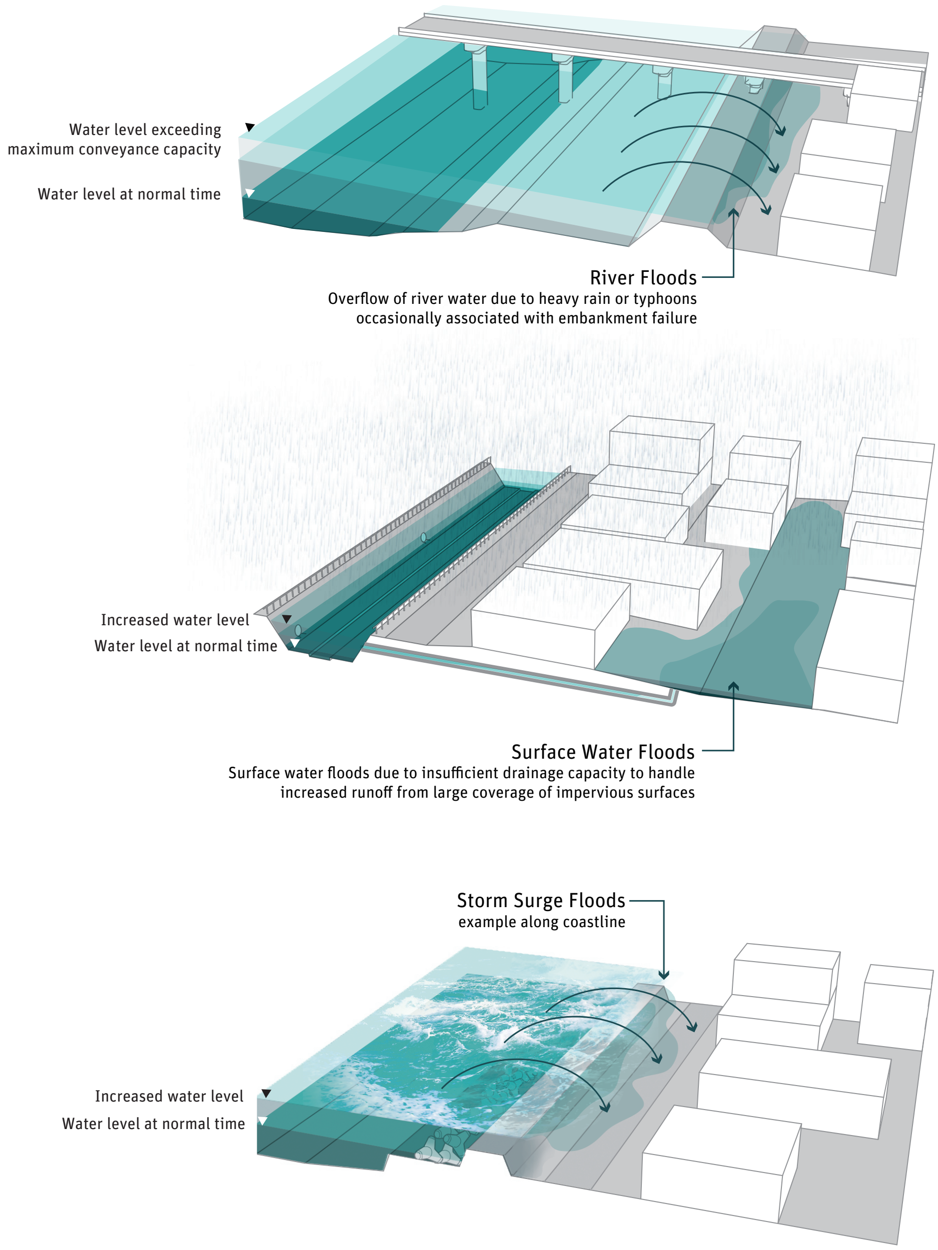
- **Learn by doing.** Japan has accumulated vast experience and know-how in different approaches and methods of urban flood risk assessment and related communication. Over the years, decision makers have increasingly focused on the objective of saving lives through risk assessment and risk communication. This is particularly critical when a flood's severity far exceeds the capacity of existing flood risk management infrastructure and facilities. In line with this, making flood risk information publicly available promotes individual-level investments. Reflecting lessons learnt, flood risk assessments need to be continuously reviewed and enhanced through research and new data, including the most recent information on inundation events, and changes in urban and infrastructure development processes, such as land use and sewerage systems.

2. Types of Urban Flood Risk

Urban floods in Japan are divided by causal factors into three categories; river, surface water, and storm surge floods (see **figure 1**). These may occur concurrently. All are generally caused by weather, such as heavy rain or typhoons. In the case of river floods, risk factors include: the location of the river and the distance between the river and the city, the river's water level compared to the ground level, and the status of flood risk mitigation measures for the river. Surface water floods generally occur when the drainage of stormwater is not managed properly during heavy rainfall in urban areas, and inundates roads and buildings. These floods typically occur in urban areas because the ground surface is covered with concrete and asphalt, which limits the capacity for infiltration and storage of storm/rainwater (see **Knowledge Note 2**). The factors that influence the risk of surface water floods in urban areas include: the capacity and development status of a city's stormwater drainage network, land use patterns, geographical characteristics, and the flow capacity of urban rivers and runnels. Factors particularly related to storm surges include the position and the distance between a city and the sea, the sea level and the ground level of the city, local topography, and the maintenance of seawalls.

Flood risks and vulnerabilities depend on key urban characteristics. These include the density of the population and assets, level of urbanization, age of the city and its infrastructure, urban development status and plans, and the capacity and development status of stormwater drainage systems, such as sewerage and river improvement systems. Geographical characteristics that affect flood risks include the position and distance of the city from rivers and/or coasts, the river water level and sea level, and the use of land. Some of the factors that influence the exposure, vulnerability, and flood risks of urban areas are listed in **table 1.**

Figure 1: Diagram of Three Types of Urban Floods



Source: Authors' compilation.

Table 1: Three Types of Urban Floods and Factors That Affect Their Risk

Factors Influencing Urban Flood Risk		River Flood	Surface Water Flood	Storm Surge Flood
Urban Characteristics				
Density (high density)		+	+	+
Maturity (age of cities, age of infrastructure, future development plans, etc.)		+	+	+
Sewerage and drainage system types / capacity (high flow capacity)			-	
Small rivers, canals (high flow capacity)			-	
Urban rivers (high flow capacity)		-	-	
Large, medium-sized rivers (high flow capacity)		-		
Tide embankment (high resilience)				-
Geographic Characteristics				
River	Proximity to rivers	+		
	Relative elevation (higher)	-		
Coast	Proximity to coasts			+
	Relative elevation (higher)			-
Topography	Flat and low elevation	+	+	+
	Gradient (not gentle)	-	-	-
	Depression	+	+	+
Land use, including soil and vegetation condition (infiltration capacity)		-	-	-

Source: Authors' compilation.
Note: Relationship of urban, geographic, and flood typologies: (+) direct relation; (-) inverse relation.

2.1 Urban Flood Risk in Japan

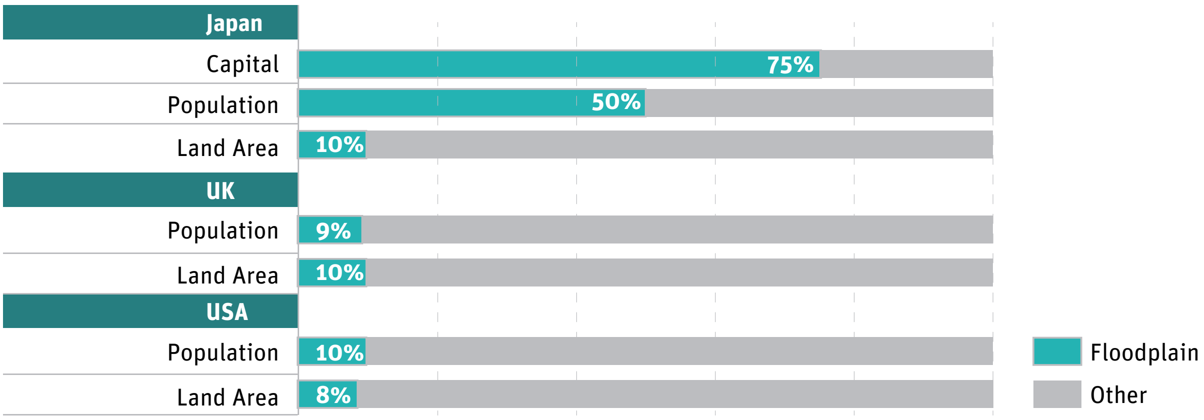
Japan's cities are at high risk of flooding due to Japan's climate, exposure to hazards, geography, history, urban and economic development context, and other conditions.[1] Japan is located at the eastern end of that part of Asia characterized by a monsoon season, and its annual average rainfall is approximately double the global average of 880 millimeters (mm). Average monthly rainfall fluctuates significantly between the rainy season and typhoon season. For example, in Tokyo, the average monthly rainfall in the wettest month of the year—September—is about five times that of December (Ministry of Internal Affairs and Communications 2017). As the frequency of localized heavy rain in Japan has increased in recent years, seemingly because of climate change, so has the occurrence of urban floods (MLIT 2015b).

Many major cities, including Tokyo, Osaka, and Nagoya, are located in flood-prone lowland areas. Because of Japan's small land mass, its population is one of the most densely concentrated in the world. The largest metropolitan areas include those of Tokyo and Yokohama (with a combined population of 39 million), Osaka (17 million), and Nagoya (10 million) (City Population 2018), all of which include low-lying areas vulnerable to river floods. In fact, Japan's population, assets, and houses are concentrated in cities with rivers flowing through them (**figure 2**) (MLIT 2002, 2007b). While so-called flood plains account for 10 percent of land in Japan, they are home to 50 percent of the total population and 75 percent of assets (Japan Institute of Country-ology and Engineering 2015).

Urban areas are also vulnerable to localized heavy rains as asphalt-paved roads and dense concrete buildings decrease the amount of storm water that infiltrates the ground, causing it to flow into the sewerage system. Approximately 80 percent of the 23 wards of Tokyo[2] have confluent sewerage systems (Bureau of Sewerage, Tokyo Metropolitan Government 2017). When a flood occurs, nearby rivers swell, increasing the risk of both surface water and river floods. As **figure 3** shows, coastal regions and cities, such as Osaka Bay, Setouchi Inland Sea, Shikoku, eastern Tokyo, and Nagoya have relatively low elevation and thus are at high risk for storm surge floods. Cities in Japan are thus vulnerable to various forms of flood risk, especially Tokyo, Nagoya, and Osaka, which have the three largest bay areas in Japan and are flat and at or near sea level.

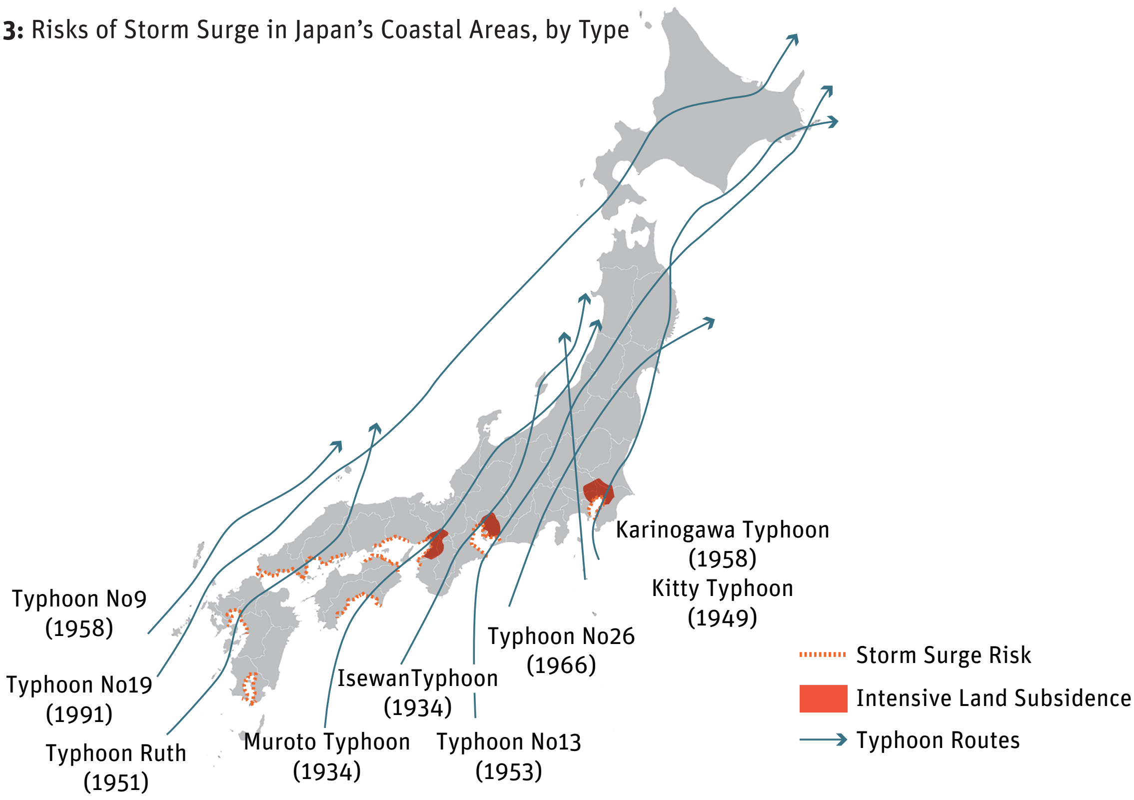
1 This series of notes understands disaster risk as the potential loss of life, injury, or destroyed or damaged assets that could occur in a system, society, or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability, and capacity, in line with the definition of the United Nations Office for Disaster Risk Reduction (UNISDR).

Figure 2: Percentage of Capital, Population, and Land Area Located in Floodplains: Japan, the United Kingdom, and the United States



Source: Modified based on information from MLIT (2007a).

Figure 3: Risks of Storm Surge in Japan's Coastal Areas, by Type



Source: Modified based on information from MLIT (2006).

2 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 (Tokyo Metropolitan Government n.d.).

2.2 Risk Assessment and Communication Objectives/Stakeholders

In general, risk assessments in Japan are conducted to support: (i) the planning and reviewing of structural flood risk mitigation and management measures, such as building embankments and other facilities; and (ii) the reviewing and adjusting of nonstructural flood risk mitigation and management measures, such as land use plans and evacuation plans. Specific objectives are listed in **table 2.**

Table 2: Objectives of Risk Assessment and Risk Communication

Risk Assessment & Risk Communication Objectives	Developed by	Used / Received by
Plan and design flood protection measures (differentiated risks / risk per flood type)	National (infrastructure / construction) government; academia; local government	National (infrastructure / construction) government; local government
Review and adjust land use plans, zoning, and building codes (combined and differentiated risks)	National (infrastructure / construction) government; academia; local government	National (infrastructure / construction) government; local government
Understand and communicate who, when, where, and how to evacuate (combined risk of inundation)	Local government; academia; civil society organizations	Local government; citizens; elderly
Develop and implement ex ante financial protection measures (combined risks)	Academia; insurance companies	Insurance companies; citizens
Integrate climate change risks into flood modeling and forecasting (combined risk and future risks)	Academia; national and local government	National and local government

Source: Authors' compilation.

There are multiple stakeholders involved in various flood risk assessments in Japan. Risk assessments are generally conducted by organizations and/or group(s) of experts and academics, who own, manage, and are responsible for developing and managing the structural facilities for flood management or areas susceptible to flood disasters. They are led by policy makers, practitioners, and city officials responsible for developing and implementing flood risk mitigation, management, and evacuation plans. The results of risk assessments are provided to organizations, institutions, and other governmental bodies that need the information.

Methodologies used in risk assessments differ based on flood types and objectives. In general, flood risk assessments are conducted according to flood type because interactions between the natural and built environments create different risks for each type of flood. In some cases, the risk assessment assumes that multiple flood incidents will happen simultaneously. **Table 3** summarizes responsible authorities, risk assessment methodologies typically employed, and assessment goals.

Table 3: Common Risk Assessment Methods, Stakeholders, and Aims

Urban Floods		Flood Management	Risk Assessment		Risk Communication
		Responsible Authority	Responsible Authority	Assessment Method	Objective
River (fluvial) floods (overflow of rivers under government jurisdiction)	Class A rivers	River, construction, and infrastructure sections under the jurisdiction of the MLIT; governors of prefectural governments	River administrators (national government)	Hydrological analysis, flood analysis / forecast	Infrastructure development and design; Evacuation warning (to local governments and community)
	Class B rivers	Governors of prefectural governments	River administrators (prefectural governments)		
Surface water (pluvial) floods (stormwater and/or sewerage system overflow)		Municipal and prefectural governments	Municipal and prefectural governments	Inland (surface water) flood analysis / forecast	Infrastructure development and design; Evacuation warning (to local governments and community – short lead time)
Storm surge floods		Prefectural governments	MLIT and prefectural governments	Storm surge simulation / forecast	Infrastructure development and design; Evacuation warning (to local governments and community)

Source: Authors' compilation.

Note: Class A river systems are those designated by the MLIT minister as important for national land conservation or economic activities. Most Class A rivers have basin areas of 1,000 km^2 or more and are used for water supply and power generation. Class B rivers are related to important public benefits and designated by prefectural governors.

3. Conducting Urban Flood Risk Assessments and Communicating Their Results

3.1 Japan's Experience with Urban Flood Risk Assessments

Methodology

Regardless of location, flood risks are assessed using simulations and analytical models. These may include the U.S. Hydrologic Engineering Center's River Analysis System (HEC-RAS) or MIKE11 from the Danish DHI (Institute for Water and Environment) (Jha, Bloch, and Lamond 2012; Rudari 2017). Essentially, analyses based on scientific evidence use hydrometeorological, hydrographical, land use, and geographical data. The methodology for conducting disaster risk assessments will be explained in more detail below, but the fundamental ideas are common: risks are assessed based on the external force of the disaster; which entities will suffer from losses and damages (as described by the urban characteristics defined in **table 1**, including population, assets, and social infrastructure); and how vulnerable or resilient these entities are.

In Japan, river administrators, sewerage system administrators, and mayors of municipalities at risk of inundation are responsible for risk assessments. These assessments in turn inform the design of urban flood management infrastructure, evacuation plans, and land use plans as per relevant laws.

Japan's river administrators determine basic policies and plans for river management, which include considering and designing infrastructure for flood measures in accordance with the River Law.

Based on the results of risk assessment simulations, river administrators determine the goals for flood measures as per the guidelines set by the national government, including the "Technical Criteria for River Works Practical Guide for Planning" (MLIT 2014). Japanese mayors of municipalities that are likely to experience river floods are required under the 2005 revision of the Flood Prevention Act to create flood hazard maps and related resources and distribute them to local residents (Ministry of Internal Affairs and Communications 2017). MLIT has published guidelines and manuals, such as the "Guidelines and Manuals for Developing River Flood Hazard Maps" (2005) and "Guidelines and Manuals for Flood Disasters Hazard Maps" (2016) to help municipal governments create their own hazard maps. Additionally, the national government supports local governments with flood risk management by providing financial subsidies, risk information, and technical support.

The time and budget constraints involved in implementing structural measures, the limits of structural measures in saving lives, and the need to advance nonstructural measures are now acutely recognized (MLIT 2009). In line with this, the development of surface water flood hazard maps became a requirement when the Flood Prevention Act was revised in 2015. The published guidelines and manuals indicate the need for the hazard maps to indicate risks from the most severe flood incident in the mapped region's history. To determine the potential inundation areas to be noted on hazard maps, simulations should be conducted if appropriate data are available; if not, historical information on inundation and geographical characteristics can be used (MLIT 2009). To assist each local government in developing hazard maps, MLIT hosts conferences and capacity-building sessions for experts and has published guidelines and manuals that local governments and cities must follow. These are regularly updated based on lessons learned from each disaster. Because a thorough PDCA cycle[3] is followed in Japan, the Flood Prevention Act was revised 19 times between 1949 and 2015, and the River Law was revised 37 times between 1964 and 2017.

Assessments inform land use plans based on the probability of occurrence (per year) and predicted level of damage (inundation depth and its extent). City governments determine land use plans, zoning, and levels and types of design requirements and standards (such as installation of rain/stormwater harvesting, infiltration and storage facilities) required for new and renovated building construction, based on forecasts of direct and indirect damage risk. For example, Shiga Prefecture utilizes flood risk assessments to demarcate "restricted urban development areas" so as to avoid critical damage to assets and the burden of recovery.

By understanding potential flood risks in each region and watershed, development plans can ensure that hard infrastructure investments are complemented by softer flood mitigation, preparedness, and evacuation measures—such as establishing and implementing effective evacuation systems, flood emergency response plans and business continuity plans, flood-sensitive siting of housing development, education and drills on disaster risk management, and so on. In addition, making flood risk information publicly available promotes individual-level actions such as investments in roof drains and the careful use of basements in flood-prone areas. Flood risk assessments need to be continuously reviewed and enhanced through research and the collection of data on flood incidents (MLIT 2012).

Assessing River Flood Risk

Generally, river and surface water flood risks are defined based on their probability and the scale of possible damage. Estimates of damage consider the external force of the disaster (hazard); damage to populations, assets, and socioeconomic activities (exposure); and the vulnerability of entities to the hazard. River flood risk assessments inform the development of river maintenance plans, evaluation of flood control projects, facility maintenance and operations, and development of evacuation directions and plans (MLIT 2012). The general process is illustrated in **figure 4.**

The first step in this process is to collect and organize data on rainfall, watersheds, rivers, flood areas, and so on. A hydrological analysis, hydraulic analysis of river flood flow, and inundation analysis consider variables such as the flow volume, water level, inundation area, transition of inundation depth over time, inundation duration, and so on. Statistics on population numbers, assets, and critical facilities are also gathered. These analyses help estimate and evaluate the event probability of floods, financial damage to general assets, potential casualties, economic damage,

3 The PDCA (Plan-Do-Check-Act) cycle is an improvement cycle based on the scientific method of proposing a change in a process, implementing the change, measuring the results, and taking appropriate action. The concept is closely linked to and developed together with the "Kaizen (good change)" concept (https://www.kaizen.com.sg/pdca-cycle/).

damage to crucial facilities, and so on, based on the "Manuals for Flood Control Survey" (MLIT 2005b) and the "Guidelines for Indicator Analysis on Flood Damages" (MLIT 2012, 2013b).

In Japan, the standard methods of flood flow and inundation analysis use a hydraulic model of one-dimensional, quasi two-dimensional, and two-dimensional flow processes. The two-dimensional model calculates variations. This model is effective for complex geography including spread-out flood plains, alluvial fans, and river mouths, but needs highly precise data and takes a long time to calculate (Jha, Bloch, and Lamond 2012).

Assessing Surface Water Flood Risk

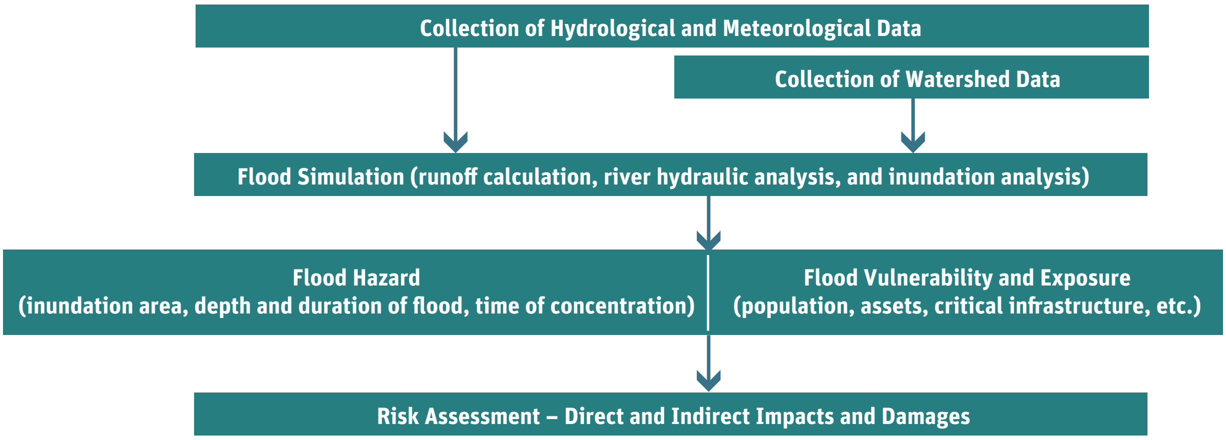
There are several similarities and differences between risk assessments for river floods and surface water floods. In general, surface water flood modelling is more complex than river modelling due to high data requirements and sensitivity to changes in the urban environment. River and surface water floods occur under different climate conditions, with varying time lags between the start of rainfall and inundation, and different frequencies of inundation. Therefore, separate risk assessments for river floods and surface water floods are needed. Despite various differences, the overall methodology is the same (described in **figure 4**). The risk assessment begins with collecting and organizing data on watershed surface water, followed by a hydrological analysis and a surface water flood analysis. The surface water flood analysis examines the level and event probability of hazards, including inundation areas in sewage watersheds, the transition of inundation depth over time, and the duration of inundation. Subsequently, population numbers, assets, and critical facilities are identified. The results of these analyses help estimate and evaluate the event probability of floods, the amount of financial damage to general assets, potential casualties, economic damages, and damages to crucial facilities.

Whenever possible, it is recommended that surface water flood risk assessments be based on inundation simulations. However, depending on local geographic contexts, needs, and limitations, assessments based on historical floods and analysis of geographic conditions (elevation data and so on) are also permitted. These general guidelines are included in the 2009 MLIT draft publication entitled "Guidelines for Creating Surface Water Flood Hazard Maps" (MLIT 2009). An alternate approach is mentioned because citywide simulations may not be required where national assessment results can be used directly, sufficient records of the flood management capacity of sewerage facilities may not be available, and municipal governments may not be able to afford preparing their own assessments. Regardless of the method, city officials must understand their local flood risks, develop hazard maps, and communicate flood risk information to citizens as quickly as possible. Additionally, flood risk assessments need to be updated regularly with the most recent information on inundation events, depth, and changes in urban and infrastructure development processes, such as land use and sewerage systems. These, along with rainfall data, may be used to predict future inundation areas.

Assessing Storm Surge Flood Risk

Risk assessments for storm surge floods are conducted by running simulations based on local natural hazard risks and conditions (e.g., high tides with strong winds). Results are utilized in designing structural and nonstructural measures, including seawalls and raised-ground areas, as well as in preparing storm surge hazard maps, particularly for logistics facilities, marine-based businesses, and industrial zones that tend to be concentrated in coastal areas. However, risk assessments for storm surge floods are not as advanced in Japanese cities as they are for river and surface water floods. In Japan, only 18 percent of the 639 localities designated as being at risk for storm surge flooding had published storm surge hazard maps as of 2013 (Cabinet Office 2014). There have been several efforts to bring together diverse stakeholders to better understand and identify storm surge flood risks. For example, the national government, port and bay area authorities, disaster prevention departments of local governments, and members of the private sector (such as factories and businesses located in coastal areas) are cooperating to enhance storm surge risk mitigation measures and secure the safety of the people who work and visit Japan's coastal areas (MLIT 2018c).

Figure 4: The Process of Assessing River, Surface Water, and Storm Surge Flood Risk



Source: Authors' compilation.

Informing the Design of Structural Flood Management Measures

River Floods

In Japan, river administrators set the goals for river development plans and design levels for flood management investments in accordance with the level of disaster management designated in the River Law. All rivers in Japan are classified by their socioeconomic significance, possible extent and nature of flood damage, past flood history, and other factors (MLIT 2018f). In line with this process, the design level of flood management investments is set according to the significance of the river. As shown in **table 4**, rivers in Japan are classified into five categories from Grade A to Grade E (where Grade A is the most significant), and each river classification has a designated flood level which the river administrator has to consider when designing flood management measures.

The design level is calculated through statistical analyses of past hydrological data and historical rainfall (MLIT 2018e). For example, major rivers of substantial economic significance (such as the lower courses of the Tone, Yodo, and Kiso rivers) are categorized as Grade A. Grade A and Grade B rivers are required to have river improvement plans and associated measures to prevent flooding in case of rainfall levels that occur extremely rarely. The main sections of Grade A rivers are generally ranked as either Grade A or Grade B, while Grade C and lower is often applied to their subsidiary streams (MLIT 2018f).

Table 4: Classification of Rivers and Design Level of Flood Management Measures

Classification of Rivers	Design Level (probability of occurrence of predicted rainfall)
Grade A	>200 (1-in-200-year rainfall)
Grade B	100–200(1-in-100- to 1-in-200-year rainfall)
Grade C	50–100 (1-in-50- to 1-in-100-year rainfall)
Grade D	10–50 (1-in-10- to 1-in-50-year rainfall)
Grade E	<10 (1-in-10-year rainfall)

Source: MLIT 2008.

Flood simulations are conducted by river administrators to identify areas at risk of inundation. In the simulations, flood plains are represented in two dimensions; computational mesh and river hydraulics are presented in one dimension, and cross-sections are made. The simulation predicts the area and depth of inundation, and the speed and direction of flood water flow driven by river overflow, rainfall, and stormwater runoff.

Surface Water Flood

Japan's national standard for flood risk management is to design and implement measures that can effectively manage a level of heavy rains likely to occur once in five years, and avoid or mitigate the inundation of assets at this level. This target level is informed by reports from agencies such as MLIT's city planning commission. The standard is applied for both structural and nonstructural flood risk management measures. For example, critical infrastructure, such as roads, powerlines, and public schools, have been developed accordingly (MLIT 2016b). So has the Comprehensive Sewerage Inundation Management Plan. (The process is further elaborated in **Knowledge Note 2.**)

As Tokyo's highly concentrated population and assets continue to grow, the city has developed one of the most ambitious urban flood risk management targets in the world. Taking a long-term view (generally 30 years), the city's flood risk management targets include: preventing flood damage from rainfall up to 60 mm/hour; and preventing flooding above ground floor level (> 50 cm) during rainfall of up to 75 mm/hour (Tokyo Metropolitan Government 2014). Kyoto, with its high concentration of historical assets, has set a goal to eliminate damage-prone flood risks in a swift manner and to avoid damage from heavy rainfall intensity of 62 mm/hour or higher (probability of 1 in 10 years). In line with this, Kyoto will set higher goals in the future as necessary (Kyoto City 2000). Sendai, with a growing population of over 1 million as of 2019, has set a goal to develop stormwater drainage facilities to avoid damages during rainfall with an intensity of 52 mm/hour (probability of 1 in 10 years) (Sendai City 2019). As of 2015, the project covered only 33.5 percent of the total area to be developed with stormwater drainage facilities (Sendai City 2019).

If appropriate rainfall data are not available, similar data for large-scale rainfall in other cities may be utilized to prepare flood plans. However, given that the risks of surface floods depend on not only rainfall but also unique urban and geological conditions, the challenges of the application of standard design levels have been highlighted by recent urban flood experiences in Japan. With the frequency and intensity of concentrated heavy rain increasing, the approaches to setting the design level for surface flood management measures are being continuously reviewed and improved in Japan (MLIT 2016b).

Storm Surge Floods

Storm surge measures in Japan, such as coastal seawalls and embankments, are designed to withstand the highest-recorded tidal surge in history. The height and design level of coastal protection infrastructure, such as seawalls, is also determined by average and record high tide levels. Predictions consider the increases in these levels due to climate change (Coastal Development Institute of Technology 2018). Each area sets its own levels based on observed data. See **box 1** for the case of a storm surge flood protection park in Kagawa Prefecture.

Box 1: A Storm Surge Flood Protection Park in Kagawa Prefecture: Assessing Risk to Enhance Storm Barriers

Takamatsu Port Shoreline, Kagawa Prefecture

Figure B1.1: Takamatsu Port Shoreline before and after the Enhancement of the Seawall

Source: Ichitanda 2008.

Objective of the risk assessment: To better protect coastal areas against storm surge floods and better predict the level of storm surges.
Type of flood: Storm surge.
Urban characteristics: Medium-sized city with a population over 331,000 (Ministry of Internal Affairs and Communications 2019).
Responsible organization: Ministry of Land, Infrastructure, Transport and Tourism (MLIT); Kagawa Prefecture.
Success factors / takeaways: Based on a reassessment of future storm surge levels, the wave breakers along the shoreline needed to be raised. A high-accuracy simulation was conducted based on an updated calibration model of wave heights. This information was also shared with citizens, whose responses informed a design that protected the scenic nature of the coastline by keeping the additional height added to wave breakers to a minimum.

Source: Coastal Development Institute of Technology 2018; Ichitanda 2008.

Source: Google Earth. *Note:* m = meter.

In 2004, Typhoon Cimaron (No. 16) made landfall in Kagawa Prefecture and wreaked unprecedented damage to the coastal areas of its capital, Takamatsu City. The level of the storm surge was far beyond the highest recorded, which led the prefectural government to reassess the level used for planning.

Based on the reassessment, the height of the existing wave breakers was to be increased by 70 centimeters (cm). However, local citizens were concerned that this would deter access to and recreational use of the shore and would disturb the scenic views. A wave-breaking shape design allowed this increase to be adjusted to 50 cm (**figure B1.1**).

This case demonstrates the importance of evaluating various solutions and approaches beyond the conventional measures for coastal flood protection. In the case of Kagawa, the objective of the risk assessment was not just to improve the design level of the existing storm surge infrastructure, but also to propose other potential structural and nonstructural options to manage the increased risks. This was made possible when technological innovation (in simulation models and creative infrastructure design) was integrated with community input.

Cost-Benefit Analysis

A cost-benefit analysis (CBA) is important to the process of assessing and designing flood risk management infrastructure. The combination of a risk assessment and CBA allows planners to investigate different investment options, and how to prioritize and select investments. Flood risk information is typically used to calculate the benefits of (or damage to be avoided by) implementing the proposed structural measures. These benefits may include the avoidance of the loss of life, direct and indirect loss of assets, decrease of land value due to inundation and flood damage, and psychological trauma that may be caused by floods. The cost is often the construction cost of the flood management infrastructure. The time frame of the investment cost and its benefits are normally taken from project investment plans. In Japan, CBA methods for flood management facilities are defined by a national guideline (MLIT 2005a).

The current CBA method includes only those benefits that are quantifiable in monetary terms, which may leave out some of the comprehensive benefits of flood management investment. Future efforts are needed to consider and integrate qualitative information in the assessment of flood management investment benefits. Some related initiatives are ongoing in Japan, such as a "Draft Toolkit for Evaluating Flood Damage Indicators," developed by MLIT in 2013. The toolkit includes methodologies for estimating qualitative flood damage parameters. Examples include: affected populations, damages to medical facilities and disaster response hub facilities, and transport and lifeline infrastructure disruptions, among others.

Informing the Design of Nonstructural Flood Management Measures

Flood risk assessments inform not only the design of hard infrastructure solutions but also the design and implementation of nonstructural measures to enhance people's preparedness and response to floods. In particular, these assessments are essential for developing flood risk scenarios that inform the design of lifesaving evacuation measures such as hazard maps, simulation training, and evacuation drills. These evacuation measures, informed by risk assessments, form a critical element of city-level disaster risk management plans.

Improving Hospitals' Preparedeness

The Ozu Memorial Hospital in Ozu City (see box 2) is a representative case of how flood risk information, together with continuous reflection, improvement, and training after each flood experience, can significantly improve the flood preparedness of critical facilities such as hospitals. It is important to understand the inundation risks in advance and utilize this information to develop a business continuity plan that outlines the clear chain of command at times of emergency, enabling the swift evacuation of patients, as well as the moving of critical medical equipment and assets to avoid flood damage.

Box 2: Enhancing the Flood Preparedness of Ozu Memorial Hospital: Assessing Risk to Help Develop a Hazard Map and Business Continuity Plan

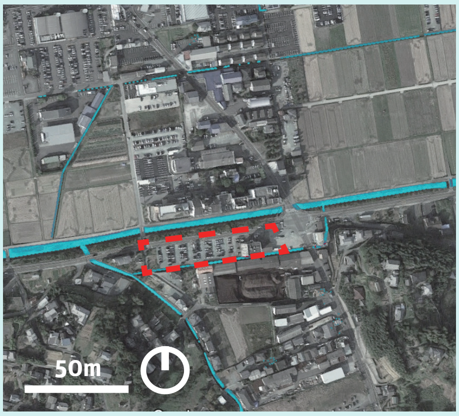
Ozu Memorial Hospital, Ozu City, Ehime Prefecture

Objective of the risk assessment: To improve the business continuity of a health-care facility for the elderly.
Type of flood: River.
Urban characteristics: Ozu is a medium-sized city located in the countryside. Its population has been decreasing since 1955 while the number of elderly people has been increasing (Ozu City 2018). As of 2015, 33.8 percent of the population were 65 years and above, or higher than the national average of 26.6 percent (Ozu City 2018).
Responsible organization: Ozu Memorial Hospital, with long-term health-care facilities for elderly people.
Success factors / takeaways: The medical facility enhanced its flood risk preparedness by utilizing hazard maps and the lessons learned from past floods to develop a business continuity plan. Through this process, flood risk assessment results were reviewed to inform evacuation methods as well as preliminary investments to mitigate potential damages. As a result, flood resilience was significantly improved.

Figure B2.1: Inundation by the Hiji River in 1995

Figure B2.2: Installation of Flash Flood Barriers by Hospital Staff

Source: Association of Medical Corporation, Jyofuukai, Ozu Memorial Hospital.



Source: Google Earth. *Note:* m = meter.

Ozu Memorial Hospital is a health-care facility for the elderly in Ozu City, Ehime Prefecture. In 1995, the hospital was inundated by flood waters from the Hiji River due to heavy rain. These cut off the building's water supply and electricity, and caused significant damage to medical devices. The hospital was again affected by Typhoon 16 in 2004, which caused inundation above the ground-floor level.

According to an Ozu City flood risk assessment conducted in 2013 and 2003, hazard maps show that Ozu Memorial Hospital is located in a flood hazard zone. The 2013 assessment indicates that if a bank of the Hiji River collapses, the hospital will be inundated by 3 or more meters of water. These results were consistent with the Hiji River Inundation Prediction Area Map published in 2003, which forecasted the area's inundation level to be between 2 and 5 meters (Ozu City 2003). Following the first flood, the hospital privately installed a power generator and water supply pumps to prevent the suspension of power or water on the second floor. This kept the damage during the 2004 typhoon to a minimum. Based on lessons learned from the 2004 typhoon, exterior water-sealing plates and waterproof doors were installed to protect rooms containing expensive medical devices such as CT scanners, MRI machines, and X-ray machines. In addition, a new hospital building that opened in 2016 was designed with car parks on the first floor and outpatient units on the second floor to minimize the effects of floods and help sustain regional health-care services (Chugoku Shimbun n.d.).

With these disaster preparedness measures, the hospital was able to minimize damages during a flood that occurred in July 2018 and resumed normal operations within three days (Ozu Memorial Hospital 2018).

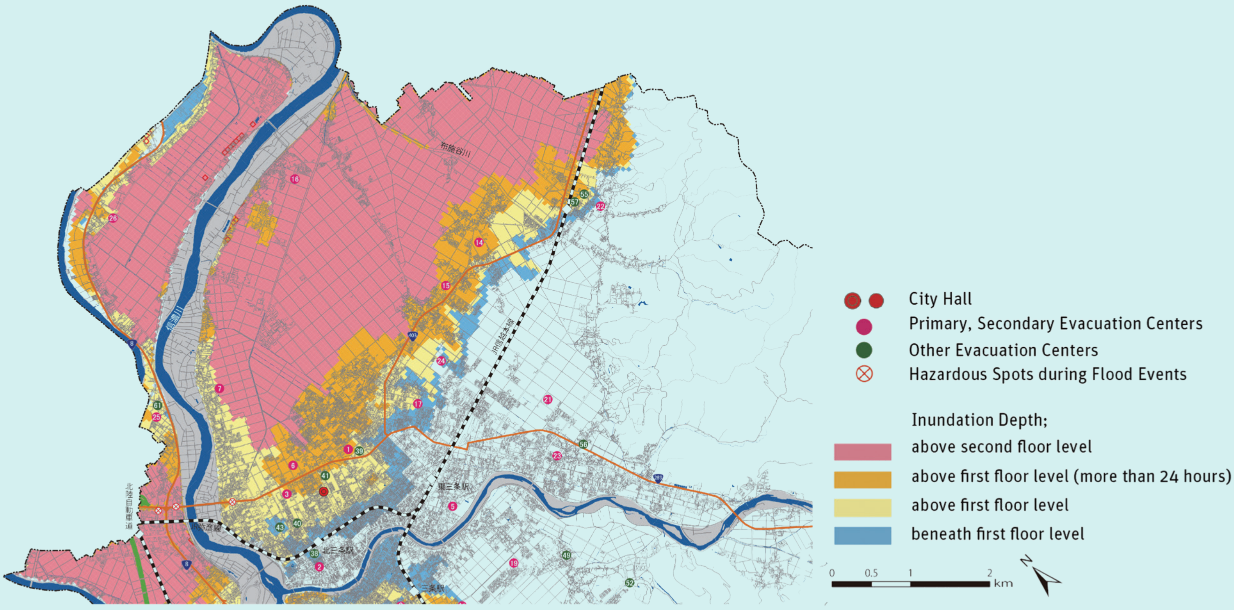
Informing Plans for Evacuation

Sanjo City, Niigata Prefecture, experienced extensive flooding in 2004, which compelled the city to enhance its nonstructural measures against urban floods to complement its structural measures. As part of this effort, the city prepared a guidebook for citizens that gave them information needed to make key evacuation decisions. The city delivered a guidebook to every household in 2011 to promote flood preparedness at the household and individual levels (Sanjo City n.d.).

Box 3: Flood Evacuation Plans in Sanjo City: Assessing Risk to Improve Citizens' Decision-Making Processes

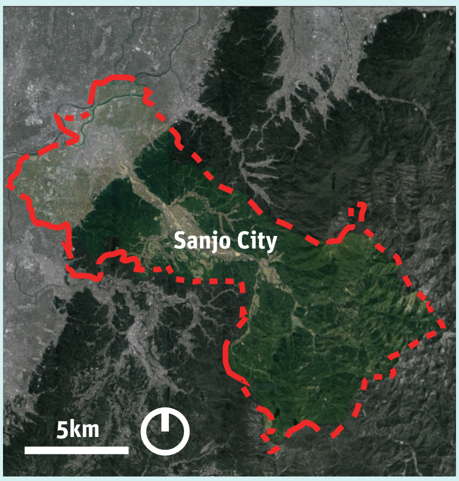
Sanjo City's Flood Risk Evacuation Map

Figure B3.1: Sanjo City's Flood Risk Evacuation Map



Source: Modified based on information from Sanjo City 2011.

Objective of the risk assessment: To develop a decision-making guidebook for citizens that helps empower them to make quick and informed decisions on where (vulnerable locations), when (timing), and how (actions to be taken) to evacuate.
Type of flood: River.
Urban characteristics: Located near Niigata City, Sanjo City is an old, historic city located on the northwestern coast of Japan. Its population was estimated at around 98,000 in 2019, and has been declining significantly since 1985 (Sanjo City 2019, Ministry of Internal Affairs and Communications 2019).
Responsible organization: Sanjo City, Niigata Prefecture.
Success factors / takeaways: Based on lessons learned from a 2004 flood, the city government created an action-oriented flood evacuation guidebook, including various hazard maps for local residents to determine and prioritize flood evacuation actions based on their own unique contexts.



Source: Google Earth. *Note*: km = kilometer.

The Guidebook for Heavy Rain Disaster Measures consists of four hazard maps for flood risk awareness, estimated inundation levels, landslide hazard zones, and timetables for evacuation. Sanjo City developed maps independently based on the city's existing flood risk assessment results. Sapporo City (Hokkaido) and Okazaki City (Aichi Prefecture) have also developed similar maps.

These maps are developed based on the same flood risk assessment results, in line with the standard national process for hazard map development. However, Sanjo City took one step forward to make this risk information accessible and usable for citizens by clarifying how various indicators relate to contextual specifics of timing, building structure, and location. Also featuring a decision tree, the guidebook is an action-oriented tool to help residents evacuate in a safe and timely manner.

The map in **figure B3.1** was created based on the lessons learned from a severe flood in eastern Japan in 2009, in which five people died from falling into irrigation channels during their attempts to escape the flood. As such, Sanjo City realized that citizens need to understand the importance of the timing of their evacuation. The map features a timetable and encourages citizens to evacuate prior to the occurrence of flooding. If the area where they are is already flooded, Sanjo City warns citizens to stay indoors and move to upper floors instead of taking escape routes as this could expose them to even greater danger. The map provides evacuation actions for residents depending on their location and residential structure.

Another map outlines the characteristics of potential inundation areas along the Shinano, Igarashi, and Kariyata rivers (Sanjo City n.d.). The map also indicates the flood risks faced by citizens' unique residential and workplace contexts, and helps them understand and adopt necessary evacuation measures depending on these characteristics. Using flood risk information to inform a combination of various tools allows for more customized evacuation instructions than do conventional hazard maps that simply show estimated damages and evacuation areas. By taking several steps beyond the status quo, Sanjo City demonstrates how risk information can be utilized to help citizens make their own decisions and be effectively prepared for evacuation during floods.

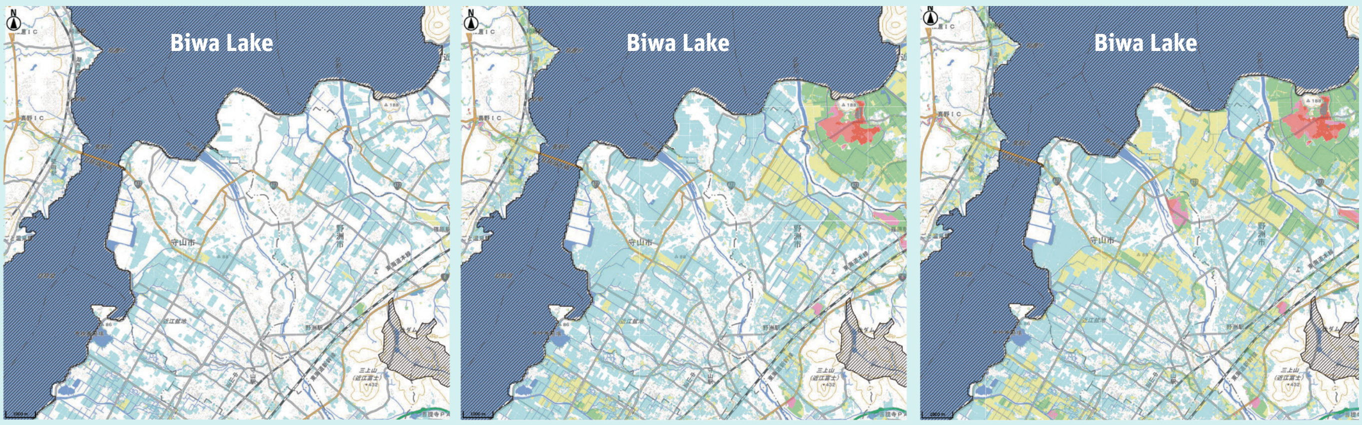
Raising Awareness of Flood Risk and Safety Measures

With unprecedented extreme weather events becoming a norm around the world, many cities are recognizing the critical importance of supporting citizens' capacities to protect their own lives and livelihoods in the face of flooding. Shiga Prefecture embarked on an effort to enhance citizens' awareness of flood risk and related safety information. Similar to flood risk hazard maps, Neighborhood Flood Safety Maps note possible areas of inundation from the overflow of small, medium, and large rivers. Each neighborhood's "safety level" is categorized by its susceptibility to surface water floods and river floods, and by how regularly these are forecasted to occur (for example, once in 10, 100, or 200 years).

Box 4: Neighborhood Safety Maps in Shiga Prefecture: Using Risk Assessments to Raise Awareness

Shiga Prefecture

Figure B4.1: Flood Depth Map by Likely Frequency of Rainfall Level



1-in-10-year Rainfall | 1-in-100-year Rainfall | 1-in-200-year Rainfall

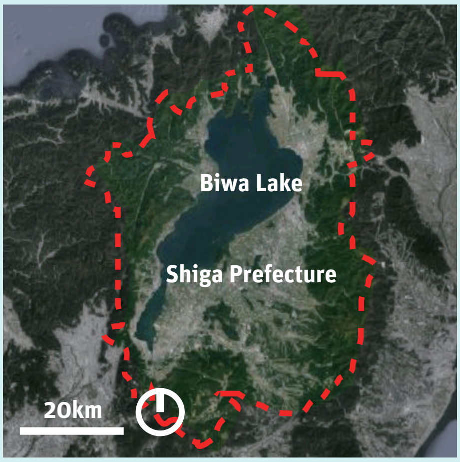
Indundation zones estimated;

less than 0.5m in depth; 0.5 - 1m; 1 - 2m; 2 - 3m; 3 - 4m; 4 - 5m

Source: Modified based on information from Shiga Prefecture (n.d.a).

Objective of the risk assessment: To promote citizens' understanding of the risks of streams and rivers overflowing into neighborhoods, and to enhance voluntary evacuation.
Type of flood: River, surface water.
Urban setting: Shiga Prefecture has a total population of approximately 1.4 million (Government of Japan 2017). Given its proximity to major cities such as Kyoto and Osaka, it is historically significant both culturally and economically. However, its population is declining and has been aging rapidly in recent years.
Responsible organization: Shiga Prefecture.
Success factors / takeaways:

- Given its rich water resources, combined with increasing heavy rains, Shiga Prefecture is exposed to high flood risks. Since infrastructure projects for flood risk mitigation and management require a long time to be completed, the prefecture has embarked on noninfrastructural measures to improve flood risk preparedness and response actions that could minimize flood impacts.
- As part of this effort, the Basic Policy for Watershed Flood Management was prepared by the prefectural government in 2012.
- Shiga Prefecture created Neighborhood Flood Safety Maps that indicate potential inundation areas from both river and surface water floods.
- By assessing various flood risks comprehensively (large and small rivers, river and storm surge floods) as well as the likely frequency of their occurrence, the assessment gathered a wide spectrum of information to share with local households and businesses.



Source: Google Earth. *Note*: km = kilometer.

Shiga Prefecture has 504 rivers, with a combined length exceeding 2,000 kilometers (km). The share of major rivers governed by the prefecture is the largest among all prefectures in Japan (Kada 2018), and therefore requires a more effective system of flood risk communication with stakeholders in the region. After an eight-year discussion with academics and local residents, the prefecture enacted the Shiga Prefecture Basin Flood Management Basic Policy (2012) (Tsuji 2014). The policy mandated that information on possible floods and inundation caused by various rainfall patterns be open to the public, which led to the introduction of Neighborhood Flood Safety Maps and increased the variety of flood risk assessment results shared with citizens. (Shiga Prefecture's urban flood risk management planning and prioritization efforts are further elaborated in **Knowledge Note 2**.) Shiga Prefecture has a high flood risk because 81 of Japan's 240 elevated-bed rivers (or about one-third) run through it. Over the past decade, the prefecture has also experienced heavily concentrated rain. Therefore, many flood risk mitigation structures and systems such as levees (ridges of earth that prevent rivers from overflowing) have been established across the prefecture. In recent years, there has been a move to utilize historical information and flood risk mitigation structures to mitigate flood risk while raising awareness of it among citizens (Shiga Prefecture n.d.[b]).

In 2012, Shiga Prefecture published neighborhood safety maps for all cities and towns in the prefecture to share information on the risks of flood damages and inform efforts to stay safe (**figure B4.1**). These new maps were different from previous versions, which focused on large rivers only. Shiga Prefecture developed its own method to translate risk assessment results into more user-friendly hazard maps illustrating the combined risks of river and surface floods, and outlining the likely occurrence of floods (once in 10, 100, or 200 years) in specific locations. This more nuanced and wide range of flood risk information at the neighborhood level was communicated to local citizens to enable evacuation plans and related community development (Shiga Prefecture 2017).

A flood inundation area map assumes a 1-in-100-year flood (approximately 109 millimeters [mm]/hour) but also shares the possible level of inundation depth of each neighborhood for floods due to rainfall levels likely to occur between once in 10 years (approximately 50 mm/hour) and once in 200 years (approximately 131 mm/hour). The flood hazard maps are updated every five years based on the status of river improvements and changes in land use (Shiga Prefecture 2017).

The example of Shiga Prefecture illustrates how sharing various types of flood risk assessment results can enhance citizens' awareness and capacity for flood risk preparedness and response. However, these must be accompanied by various educational and communication efforts to help citizens understand and interpret the information, and translate their knowledge into effective action.

Integrating Climate Change Considerations into Assessments of Urban Flood Risk

Importance and Challenges

Amid climate change, Japan's maximum annual precipitation level is expected to increase by a factor of between 1.1 and 1.3 by the end of the 21st century, compared with today's levels (MLIT 2015g). At the same time, it is estimated that the frequency of floods exceeding the design level of flood management measures in place will increase between 1.8 and 4.4 times, possibly causing devastating flood damage. Low-lying lands and areas below sea level, often in urban areas, are expected to be inundated for extended periods by river, surface water, and storm surge floods. For instance, areas below sea level along the bays of Tokyo, Nagoya, and Osaka, the three largest metropolitan areas in Japan, are likely to face much higher flood risk. Based on the assumption that sea level will increase by 80 cm by the year 2100, the size of areas below sea level will increase by 60 percent, and the population at risk in these areas will increase by 40 percent. Integrating these and related estimates into flood risk assessments, especially for urban areas, is critical in order to mitigate and respond to floods effectively.

The effects of climate change are predicted to vary from place to place, based on unique geographic and urban contexts. Therefore, location-specific estimates of how climate change might affect flood risk are quite important. But the quality and detail of existing forecasts are limited by the current state of spatial resolution technology. To counter this, Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) has launched an initiative to conduct 12 research programs on climate change adaptation. These include supporting the research and development of a management system for river and water resource areas to address climate change, technological solutions that facilitate the application of global climate change forecasts to regional and local assessments, and climate change simulation technology (Ministry of Education, Culture, Sports, Science and Technology 2010). Few cities to date have conducted their own climate change impact assessments or applied these to flood management plans.[4]

Current Approach

After Japan saw unprecedented flood levels across many regions in 2015, the national government initiated efforts to integrate climate change risks into flood risk management efforts. These highlight the importance of planning for both manageable and unmanageable flood risks, and using both structural and nonstructural measures (MLIT 2015a). Several committees[5] and working groups convened by MLIT have been discussing measures to address flood disasters caused by climate change. In 2015, MLIT published an interim report that outlined Japan's policies and guidelines based on a review of various climate-smart flood management approaches trialed in the European Union and United States (MLIT 2015c).

4 The Tokyo Metropolitan Government conducted a climate change impact assessment in partnership with the National Institute of Environmental Science (NIES) and MEXT for 2009–12 (https://www.iges.or.jp/files/research/natural-resource/PDF/20140326/2-3_shirai.pdf).

5 For example, in April 2018, the MLIT established a committee called the "Flood Risk Management Review with Climate Change Consideration" to discuss risk assessment methodologies to reflect changes in risk due to climate change (MLIT 2017b).

To make flood measures resilient to climate change risks, the report highlights the importance of: (i) designing and implementing flood management measures with the assumption that unprecedented levels of hazards will occur, and facility managers may have to cope with both manageable and unmanageable levels of rainfall; and (ii) helping citizens understand that public sector initiatives alone may not be sufficient to protect their lives and livelihoods, and so they must strengthen their knowledge of risks and safety measures. While these efforts are still in their nascent stage, some legal frameworks such as the Flood Control Act (updated in 2015) have integrated these principles, such as the need to prepare for not only the highest watermark in recorded history but also for unprecedented events.

While the flood risk level considered for structural measures remains the same (that is, high-frequency rainfall levels), a different approach is proposed for nonstructural measures. Differences between the current flood risk management approach and the proposed climate adaptive approach are elaborated in the "Interim Report on Flood Disaster Measures Resulting from the Climate Change" (MLIT 2015c, 2017a) and summarized in **table 5.**

Table 5: Approaches to Flood Risk Assessments with and without Climate Change Considerations

	Current Approach (without climate change consideration)	Proposed Approach (with climate change considerations)
Design of flood management infrastructure (structural measures)	• Design of infrastructure investment is based on flood management of sewerage facility development plans and river improvements plans. • Based on these plans, the infrastructure facilities are designed to manage **high-frequency flood events (i.e., floods from rainfall that occur once every few decades to every few centuries).**	• Given that flood management infrastructure development has not yet met the planned level, **the design level remains the same with climate change considerations.** • Therefore, infrastructure facilities are designed to manage **high-frequency floods (i.e., due to rainfall levels expected every few decades to every few centuries).**
Preparing for floods beyond the capacity of existing flood management infrastructure (nonstructural measures)	• Enhance preparedness, mitigation, and response actions by diverse stakeholders by developing and disseminating flood hazard maps and business continuity plans. • Hazard maps are informed by risk assessments based on **high frequency floods (i.e., due to rainfall levels expected once in every few decades to every few centuries)**.	• The general approach toward enhancing flood preparedness, mitigation, and response actions remains the same, such as developing and disseminating flood hazard maps, preparing business continuity plans, and enhancing evacuation. • However, the risk assessment differs, as it considers **floods that may occur with maximum precipitation (a probability of approximately 1-in-1,000-years).**

Source: Authors' compilation based on MLIT (2015c).

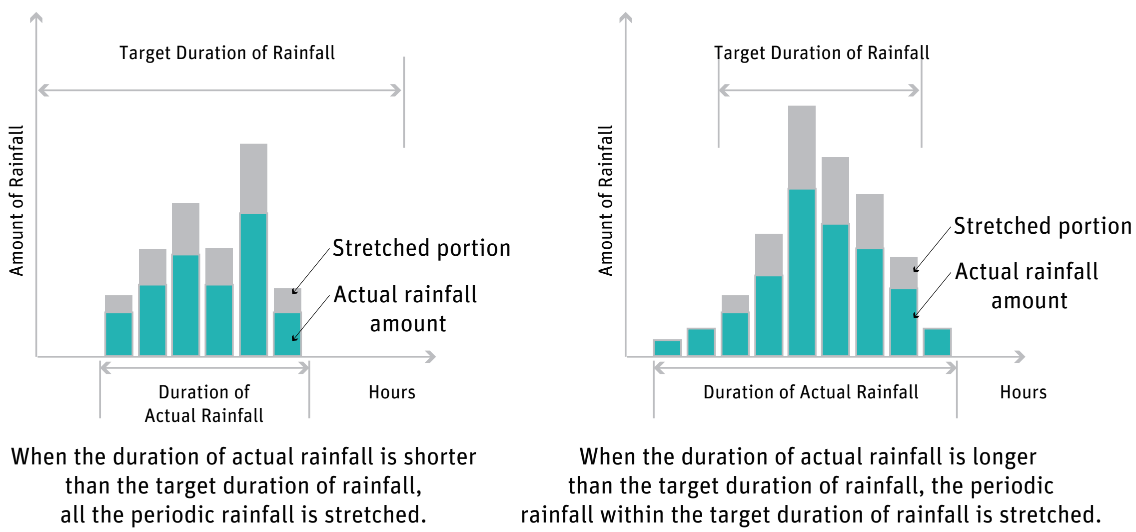
Building on these overall approaches to promoting climate resilience, climate change risks are integrated in flood risk assessments by considering two key parameters: (i) river and surface water floods at historically high levels, and (ii) storm surge floods with a 1-in-1,000-year probability (MLIT 2015d).

Integrating Climate Change Considerations into Risk Assessments for River and Surface Water Floods

Drawing upon experiences and lessons learned in Europe and the United States, the Flood Risk Assessment Guidelines developed by the second Technical Committee for Flood Management Plans Taking into Consideration Climate Change Risks and Impacts suggests that, to consider climate change risks, flood risk assessments should review multiple rainfall scenarios (MLIT 2018b). The guidelines recommend that risk assessments be conducted using precipitation scenarios for: (i) targeted flow volume defined in river improvement plans; (ii) scale as per the Basic Policy of river development plans; (iii) the probability that an annual event will be of the magnitude of a 1-in-200-year or even a 1-in-500 year event; and (iv) the probable maximum precipitation (or probability of 1 in 1,000 years) (MLIT 2018b). Additionally, risk assessment results are to be cross-checked with hyetographs, where rainfall must not exceed 220 mm/hour or 60 mm/10 minutes, which is the theoretical maximum level of rainfall that is used to define an "extreme event" (MLIT 2018b).

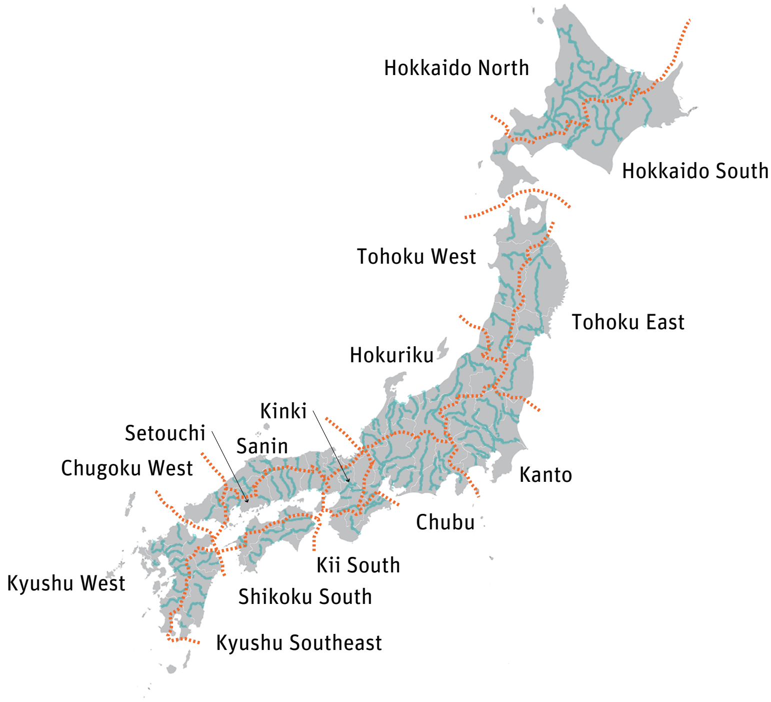
Risk assessments require information from hydraulic, hydrological, and meteorological observations, such as the rainfall depth, water level, and flow rate of rivers and sewerage systems, capacity of river and sewerage facilities, and past recorded flood levels. These data include two key parameters: rainfall depth and hyetographs. Hyetographs show the spatial distribution of rainfall intensity over time. Floods due to maximum precipitation levels are forecasted based on the maximum rainfall volume affecting not only the target river but also neighboring rivers. The probable maximum hyetograph is set based on the hyetograph used for the river improvement basic policy and/or the hyetograph of recent major floods. The probable maximum hyetograph is stretched to the level equal to the probable maximum precipitation of each geographical area in order to consider extreme weather events that may be induced by climate change (see **figure 5**). Flood risk assessments that integrate climate change risks are conducted regionally in Japan. Fifteen geographic areas are identified for the risk assessment, grouped based on similar levels of probable maximum precipitation (see **figure 6**). The maximum rainfall volume for each geographic area is set based upon the highest level of probable maximum precipitation, also called the local maximum rainfall (MLIT 2016a).

Figure 5: Estimating Maximum Rainfall Considering the Effects of Climate Change



Source: Authors' compilation based on MLIT 2015d.

Figure 6: Regional Flood Risk Assessment, by Probable Maximum Precipitation Levels



Source: Authors' compilation based on MLIT 2015d.

Integrating Climate Change Considerations into Risk Assessments for Storm Surge Floods

In the case of storm surge floods, the current method of integrating climate change risk is to use the largest typhoons that Japan has ever experienced (approximately 1-in-1,000-year events) to identify high-risk inundation areas based on the simulation of multiple routes with the highest sea-level departure.[6] Estimates center on the Muroto and Isewan typhoons. The maximum strength of central atmospheric pressure is based on the Muroto Typhoon, which was categorized as a 1-in-1,000-year event. The simulation is calculated by adjusting the typhoon's central atmospheric pressure to the latitude of the coastline in question. A storm's predicted maximum radius and travel velocity are based on the Isewan Typhoon, which was larger and faster than the Muroto Typhoon. In addition, combined flooding scenarios are prepared by predicting the worst-case scenarios related to excessive river flow volume, high tide level, and levee failure (Ministry of Agriculture, Forestry and Fisheries and MLIT 2015).

Integrating Climate Change into Hazard Maps

To prepare for climate change risks and to inform evacuation plans, cities are developing hazard maps based on flood risks and impacts from probable maximum flood strength, as in five neighboring low-lying wards of Tokyo. Hazard maps created by some cities and wards in Tokyo set a target flood management level equivalent to a 1-in-1,000-year flood. This is in accordance with Tokyo Metropolitan Government's Basic Policy for Heavy Rain Measures, revised in 2014, which is further introduced in **Knowledge Note 2** (Bureau of Construction, Tokyo Metropolitan Government 2018).

6 Tide-level departure refers to the difference between the astronomical tide level and high tide caused by typhoons and tropical depressions (https://www.jma.go.jp/jma/kishou/know/typhoon/4-1.html).

To make sure hazard maps stay responsive to climate change, it is important to update them with the latest lessons learned. Large-scale floods in the Kanto region (surrounding Tokyo) and Tohoku region (the northern part of Japan's main island) in 2015 revealed that traditional hazard maps did not indicate the risks of buildings being washed away or the possibility of long durations of inundation, but focused more on inundation area and depth. As a result, citizens could not utilize the hazard maps effectively to plan for an effective mitigation or response strategy. Lessons should be integrated into risk assessments and hazard maps at the local level, as well as within the national guidelines. For example, based on 2015 flood experiences, in 2016, MLIT published new hazard map guidelines integrating river, surface water, and storm surge floods (Nihon Suiko Sekkei Company Limited 2016).

Enhancing the usability of hazard maps to improve citizens' flood preparedness and evacuation plans is a vital step. User-friendly maps that integrate climate change considerations include the following characteristics:

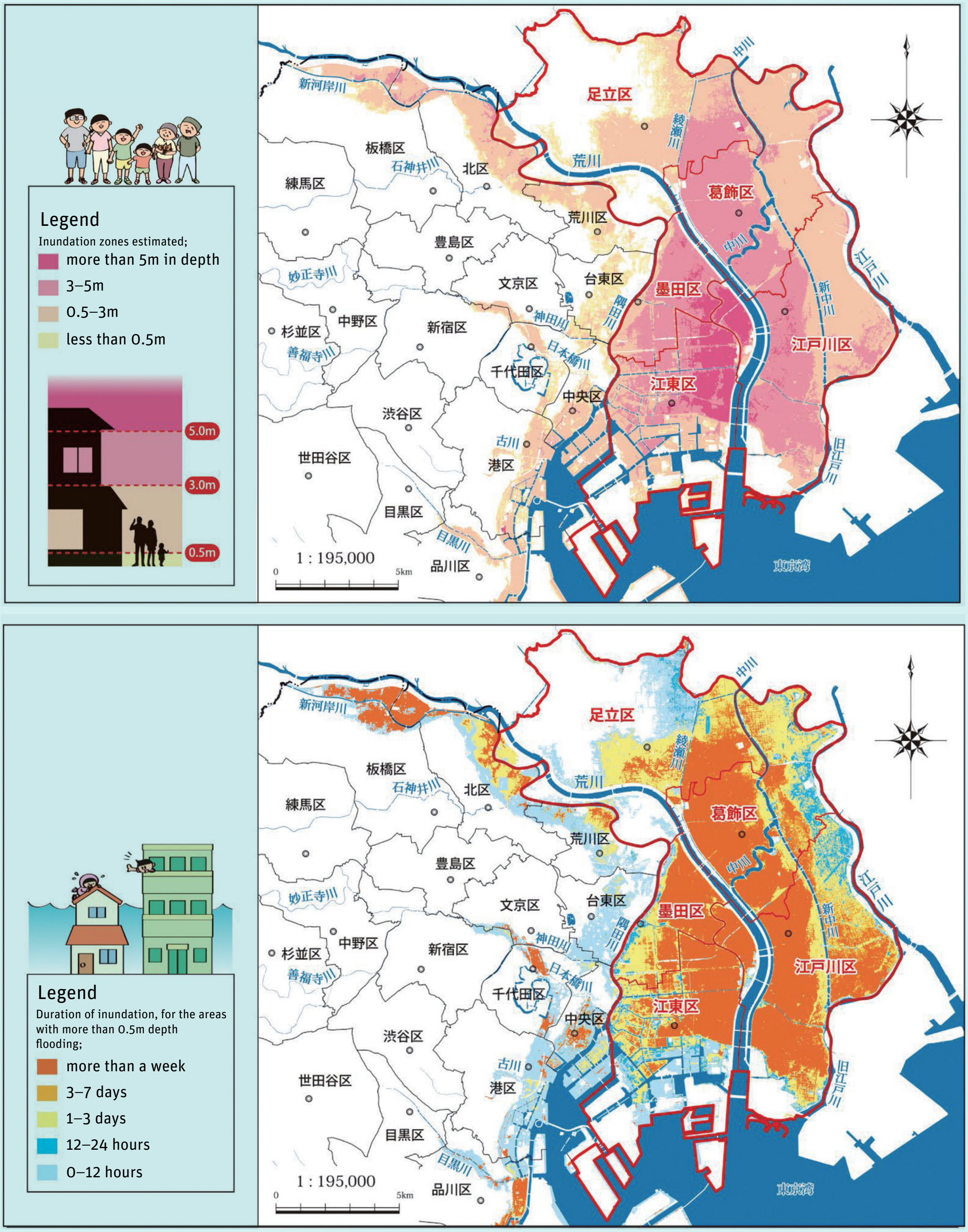
1. **Climate change risks are clearly noted**–maximum flood strength is set as a baseline.
2. **Information is local and detailed**–maps are customized to each community and by flood type and local geographic and economic conditions.
3. **Evacuation decisions are supported**–maps inform users *who*, *when*, and *where* to evacuate.
4. **Actions to be taken before and after floods, to enhance preparedness and response are recommended**–two sets of information are provided: one for normal (nondisaster) times, to understand the risk, and the other to refer to during evacuation in times of disaster.

See **box 5** for examples of enhanced hazard maps made by a consortium of five Tokyo wards.

Box 5: Integrating Climate Change into Hazard Maps: Regional Evacuation Plans for Large-Scale Floods in Tokyo

Five neighboring wards (Sumida, Koto, Adachi, Katsushika, and Edogawa), Tokyo

Figure B5.1: Flood Hazard Maps for the Public: Projected Inundation Depth Map (above) and Inundation Duration Map (below) of Five Wards in Tokyo



Source: Council for Koto 5 Wards Wide Area Disaster Evacuation 2018a.

Objective of the risk assessment: To understand likely inundation areas and their depths, duration of inundation, and effects on buildings in five wards of Tokyo and to develop a regionwide evacuation strategy for citizens to ensure safe evacuation locations, methods, and timing in case of extreme flood events.
Type of flood: River, surface water, storm surge.
Urban characteristics: East of Tokyo with dense population and businesses located in wide coastal areas below sea level.
Responsible organization: Wards of Tokyo Metropolitan Government.
Success factors / takeaways: Five neighboring wards that have vast areas below sea level and share the same flood risks collaborated to conduct a risk assessment of probable maximum floods, considering climate change impacts. The assessment revealed the need to promote awareness among citizens of the potential for widespread, long-lasting floods and voluntary evacuation at an early stage.

Five neighboring wards in Tokyo (Sumida, Koto, Adachi, Katsushika, and Edogawa) offer an example of how vulnerable cities can collaborate to understand the potential devastating risks of extreme floods from climate change, and develop a joint solution to ensure safe evacuation. These wards include three major rivers (the Sumida, Arakawa, and Edogawa) as well as many smaller rivers. In addition, the area is located below sea level, making it particularly vulnerable to flood damage, and is densely populated with many residential zones and high-value assets. Historically, it has repeatedly suffered damage from devastating typhoons such as Typhoon Kathleen (1947) and Typhoon Kitty (1949). Significant damage was caused by not only the wide area of inundation but also the long duration of the floods due to difficulty draining flood waters. For example, some districts of this area may stay inundated for more than two weeks if large-scale floods destroy the embankments along the Arakawa and Edogawa rivers. As climate change brings about more extreme events, the approximately 2.5 million people living in the five wards are exposed to significantly greater flood hazards.

In light of this concern, in 2016, the five wards collaborated to establish the Council for Koto 5 Wards Wide Area Evacuation. The council invited academics to advise plans for large-scale evacuations that would require complex coordination among many stakeholders. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT), the Tokyo Metropolitan Government, and transportation operators were invited to observe the council's discussions. The council developed two evacuation maps in 2018: "Wide Area Evacuation Plans for Large Scale Floods in Koto Five Wards" and "Floods Hazard Maps for Large Scale Floods in Koto Five Wards." Through a collective effort, the wards are working to create a regional evacuation plan that would define the collaboration of neighboring municipalities and enhance residents' capacity to voluntarily evacuate when needed to safe sites located outside their neighborhoods (Council for Koto 5 Wards Wide Area Disaster Evacuation 2018b).

Figure B5.1 shows the projected inundation areas of the five wards. The image at the top shows the depth of inundation, while the image below this shows the duration. These maps were created by combining the inundation data from the Arakawa and the Edogawa rivers from a scenario that requires both rivers to be flooded from three consecutive days of rain—a 1-in-1,000-year occurrence, with a total rainfall of 632 millimeters (mm) and 491 mm for the Arakawa River and Edogawa River, respectively.

The extent of possible damage was also discussed at meetings on the impacts of climate change in the area. According to the MLIT's Office of Water Management and Homeland Protection, if probable maximum rainfall occurs along the Arakawa River and causes a failure of one section of the levee, there would be a maximum of $250 billion in economic damages (14-month accumulative damage) and $360 billion in asset damages over the course of a year.

3.2 Japan's Experience in Urban Flood Risk Communication

The overall objective of flood risk communication is to encourage and guide actions that mitigate and prevent flood risk by disseminating the right information, to the right stakeholders, at the right time, through the right channels. Methods of flood risk communication differ according to the goals and phases of a flood incident, such as before, during, and after floods, as well as during recovery.

Enhancing Preparedness

Risk assessments, if communicated effectively before disasters, can support the preparedness and mitigation efforts of citizens and other stakeholders. This can significantly reduce losses and damages to lives and livelihoods. Strengthening the capacity of individuals and communities to prepare for, mitigate, and respond to floods through their own efforts is extremely critical, especially since structural measures have their limits. Floods may occur before enhancements to existing infrastructure are complete, as construction generally spans long periods of time. Therefore, it is important to effectively communicate information needed to prepare for a flood beyond the level that existing or planned infrastructure enhancements can handle.

In order to trigger swift evacuation and response when flood events are detected, cities are making accurate and real-time risk information available to citizens through "push" and "pull" methods. Technological advancement has drastically improved last-mile flood risk communication and early warnings throughout the world. In Japan's case, local governments have been utilizing information and communication infrastructure and devices to enhance flood and other disaster risk communications. Many municipalities make local flood risk information available online so citizens and stakeholders can "pull" almost real-time information from these platforms anytime. Also, in recent years, national and local governments can increasingly "push" information on early flood warnings, a rise in forecasted levels, and evacuation plans directly to mobile devices, televisions, radio signals, and so on.

For example, in 1988, the Tokyo Metropolitan Government's Sewerage System Management Division introduced a rainfall information broadcasting system called Tokyo Amesh. The MLIT also uses a highly accurate (the smallest observation unit is 250 square meters) and real-time (data are renewed every minute) radar system (MLIT 2013a). The Tokyo Metropolitan Government has started using the cutting-edge Multi Parameter (MP) radar, which enables detection of very subtle rainfall of 1 mm/hour. This highly accurate information is delivered to personal computers and mobile devices so that residents can prepare for floods (Bureau of Sewerage, Tokyo Metropolian Government n.d.).

Enhancing the communication of flood risk to operators of critical infrastructure, such as roads and rails, and water supply, sanitation, and power companies can significantly improve flood risk management and response in cities. **Boxes 6** and **7** outline communication and response measures implemented by railway and metro operators.

Box 6: Disseminating Flood Risk Information: The "Timeline" Method Used by Urban Railways

Objective of the risk assessment: To mitigate chaos during a flood by providing companies and schools early notice of suspended train operations by major railway companies, well in advance of the expected heavy rain and/or associated flood event.
Type of flood: River, surface water, storm surge.
Urban setting: In the Tokyo Metropolitan Area and Kansai Metropolitan Area (including Osaka and Kyoto) alone, Japan's railways carry more than 21 million passengers a day (JR East n.d.; JR West n.d.).
Responsible organization: Ministry of Land, Infrastructure, Transport and Tourism (MLIT), private railway companies, including JR West.
Success factors / takeaways: The MLIT led the initiative to create "Timeline-Based Disaster Prevention Action Plans" outlining a detailed list of actions to be implemented by railway companies in metropolitan areas to ensure the continuation and/or quick recovery of operations after a flood event. Given the importance of rail transport in Japan, the Japanese government encouraged the adoption of the measures within specified time frames by railway companies, local governments, and other relevant stakeholders.

The concept of timelines drew attention when Hurricane Sandy struck New Jersey in the United States in October 2012. Swift disaster prevention actions were taken according to a prepared timeline that set the hurricane's predicted landfall as the "zero" hour. The governor of New Jersey published evacuation recommendations 36 hours before this and called for emergency evacuation 12 hours before the zero hour for those who remained behind. Plans outlining who was to do what and when were decided before the disaster and shared with all stakeholders (MLIT 2015e).

Based on the U.S. experience with Hurricane Sandy, in 2014 MLIT established a working group to tailor the timeline-based approach to Japan's context; the group published "Timeline-Based Disaster Prevention Action Plans" and other guidelines in 2016. By 2017, all 730 of the municipal governments located in flood-prone areas completed timelines for early evacuation advisories.

Benefits of the timeline-based action plans included clarifying the responsibilities of disaster prevention authorities, outlining appropriate actions for disaster prevention, and verifying and improving disaster measures. During the devastating floods caused by heavy rain in 2015, 72 percent of municipal governments with timeline-based action plans were able to swiftly warn citizens to evacuate, whereas only 33 percent of those without the timelines were able to do this. These statistics clearly show how such plans help city authorities make timely and effective evacuation announcements, and as a result save lives and assets in the face of floods (MLIT 2015f).

In 2014, JR West started issuing advance notice of the suspension of train operations due to typhoons and/or heavy rain. The company's action plan includes the following: issuing advance notice of the suspension of train operations two days before a typhoon's arrival, through various means such as in-train announcements and the Internet; partial suspension of train operations during heavy rain and publication of timetables on websites and other outlets; specific actions around the disruption of train services, facility protection, and evacuation during a typhoon; and the announcement of resumed train services after a typhoon passes (Yahoo Japan 2014).

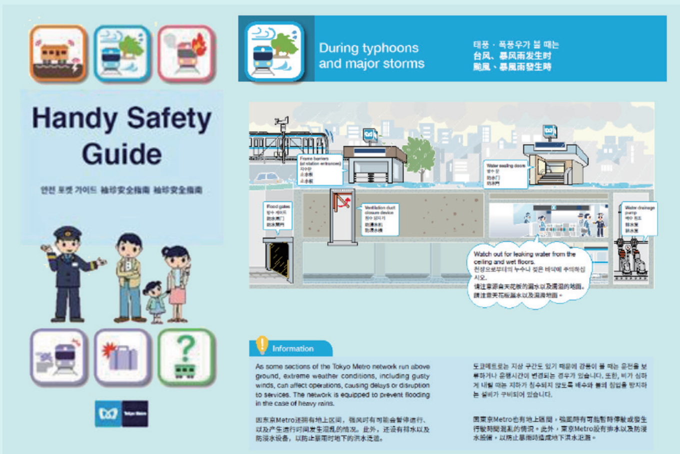
In a 2018 review of action plans conducted by MLIT and railway companies, an interim recommendation was that the suspension of train service be announced earlier, more widely, and in multiple languages. The review also noted that information provision to local governments and collaboration among railway companies were essential to streamline the resumption of services (MLIT 2018d).

Box 7: Disseminating Key Information through Multiple Means: The Case of Tokyo Metro

Figure B7.1: Signboard Indicating the Elevation of the Station Entrance Compared with Sea Level

Source: Economic Research Association (2018).

Figure B7.2: Handy Safety Guide (Evacuation Handbook for Subway Passengers)



Source: Tokyo Metro (2018).

Objective of the risk communication: To disseminate updated information on heavy rains, flood warnings, and evacuation procedures via announcements and displays at subway ticket gates, with the aim of helping metro users make informed decisions, evacuate safely and quickly, and mitigate their personal risk.
Type of flood: River, surface water, storm surge.
Urban setting: Capital with dense population and assets.
Responsible organization: Tokyo Metro.
Success factors / takeaways: Tokyo Metro has been implementing various flood-related measures in subway facilities. As part of its communication efforts, the company distributes Handy Safety Guides in multiple languages to subway passengers and displays disaster information at ticket gates. An online meteorological information system disseminates updated data to subway employees so that they can swiftly share precise information with passengers and decide when to resume operations.

Tokyo Metro operates nine subway lines mainly in the Tokyo Metropolitan Area. The lines cover a total of 195.1 kilometers (km), service 179 stations, and accommodate 7.24 million passengers daily. As of 2018, 168.6 km (86.4 percent of the total service distance) and 158 stations (88.2 percent of all stations) were underground. Tokyo Metro has been addressing the disaster resilience of underground metro systems for a long time by focusing on measures to mitigate and manage underground inundation caused by the overflow of small rivers. The company is also considering the risks of underground inundation due to extreme weather events, such as concentrated heavy rain as well as a possible major flood of the Arakawa River due to changing rainfall patterns (Economic Research Association 2018).

Tokyo Metro has been implementing various new flood measures, including installing flood prevention equipment on the ceilings of subway tunnels and waterproof sealing plates at subway entrances. These measures consider a worst-case scenario with deeper inundation depths than those listed on the MLIT's inundation maps of Grade A rivers or the Tokyo Metropolitan Government's inundation maps of small- and medium-sized rivers. Other existing flood measures include constructing entrances higher than street level and installing waterproof doors and sealing plates at ground-level entrances. In case of immense water flow into underground tunnels, flood prevention gates are installed at various points to close tunnels, and pumps are installed to help get water out (Tokyo Metro n.d.).

In accordance with the Flood Prevention Act, 40 Tokyo Metro stations have prepared evacuation and flood prevention plans. The plans require Tokyo Metro employees to lead subway passengers in the event of an evacuation and indicate the evacuation routes and places where water sealing plates are installed (Tokyo Metro 2015). In addition, the municipal government has conducted emergency drills in collaboration with various stakeholders (local citizens, fire and police departments, and other transport operators) to simulate emergency exercises (Tokyo Metro 2016).

To effectively communicate risk and inform subway passengers of proper actions to take during a flood, the Handy Safety Guide (Tokyo Metro 2018) was prepared in multiple languages and has been distributed at all Tokyo Metro stations since 2012. Screen monitors have also been installed at the fare gates of every station to provide weather, train operation, and disaster emergency information from the NHK public TV station. Risk and weather forecast information from the Meteorological Agency is disseminated through the Tokyo Metro Online Climate System to subway employees. This information allows employees to make informed decisions regarding the operation and regulation of train services. In addition, signboards are displayed at station entrances; they indicate the relative elevation of the station compared with sea level, and promote awareness of evacuation procedures (Economic Research Association 2018).

Improving the communication of flood risk and safety measures to vulnerable people such the elderly, people with disabilities, and children is extremely critical to enable their safe evacuation. Box 8 outlines flood risk communication and response measures implemented in Sanjo City to support the evacuation of those needing assistance.

Box 8: Evacuation Measures for Those in Need of Assistance in Sanjo City

Objective of the risk communication: To share flood risk information and secure the effective evacuation of vulnerable citizens in need of assistance during a disaster.
Type of flood: River, surface water.
Urban setting: Located near Niigata City on the Sea of Japan coast, Sanjo has a population of 98,000. This population is aging and has been decreasing since 1985.
Responsible organization: Sanjo City, Niigata Prefecture.
Success factors / takeaways: The municipal government recognized: (i) the limited capacity of communities to provide assistance to those in need during an emergency; and (ii) the privacy concerns of individuals who refused to be listed on a roster of people needing assistance. The city revised the registration criteria to limit the number of listed citizens and target assistance to those most in need.

Those in need of special consideration during evacuation include the elderly, those with disabilities, infants, and anyone with difficulty moving independently (Sakai City 2014).

Sanjo City experienced nine casualties, of which seven were elderly citizens, during a river flood in 2004. This incident highlighted the need for evacuation measures that enlisted community help to assist those in need. The city started listing those in need of assistance in 2005 and continuously updated the list every six months with the help of community leaders (Ebina 2014). Until 2017 the city used data from long-term care insurance providers to identify those who could not evacuate on their own or with their families. However, the 4,842 citizens who needed assistance according to these criteria were too many for local communities to manage. Also, due to privacy concerns, some of these individuals did not want to register and be identified as people in need.

The municipal government therefore applied new criteria to narrow down the number of those in need of assistance by focusing on households inhabited by the elderly and those with disabilities. Eventually 2,216 individuals were identified as those in need of community assistance during an emergency. Prioritizing saving lives during an emergency over privacy concerns, the city adopted a new rule that all citizens in need must register, but once registered they can apply to be removed. Under this new system, the number of those who chose not to be registered decreased to 5 percent by 2014, compared with 18 percent in 2007 (Sanjo City n.d.).

Since flood risks, city contexts, and technological advancements evolve rapidly, it is very important to monitor, evaluate, and improve flood risk communication methods after each flood event. Another example from Sanjo City (**box 9**) highlights how evaluating flood risk communication after each disaster event, and making improvements based on those findings, can be instrumental in improving flood risk communications and minimizing the impacts of future flood events.

Box 9: Assessing and Improving Risk Communications after Floods in Sanjo City

Objective of the assessment: To review and evaluate the risk communication implemented after flood events to determine areas for modification and improvement
Type of flood: River.
Urban characteristics: The population of Sanjo City is approximately 98,000, and has been decreasing since 1985. It is located near Niigata City, a city with an aging population of 800,000 on the coast of the Sea of Japan.
Responsible organization: Sanjo City, Niigata Prefecture.
Success factors / takeaways: After a large-scale flood event in 2004, the city conducted a review of its risk communication and identified several bottlenecks. Based on a postdisaster survey conducted in collaboration with a university, areas for improvement were addressed, resulting in the enhancement of risk communication in Sanjo City.

In 2004, the Igarashi River flooded Sanjo City, causing severe damage. The year's total rainfall of 491 millimeters (mm) broke records. This experience exposed several problems in the city's communication of flood risk, including the chaotic management of disaster control headquarters; difficulties in deciding when to order evacuation;

inadequate information dissemination systems; and inadequate assistance of elderly citizens.

The city conducted a survey of its citizens to examine their behaviors and the status of risk communication at the time of the disaster. Based on the survey results, both structural and nonstructural measures were developed and implemented.

The city experienced another period of heavy rain in 2011 with a total rainfall of 959 mm, twice as much as in 2004. The rainfall caused damage, including a levee collapse in the upper course of the Igarashi River and landslides in the mountains. But as a result of improved risk communication measures developed after 2004, overall damages were limited. Changes included increased use of information dissemination systems and methods, updated flood disaster manuals, and publication of guidebooks for heavy rain disasters including Flood Risk Evacuation Maps (see **box 3**), and the enhancement of life-saving disaster measures (see **box 8**) (Sanjo City n.d.).

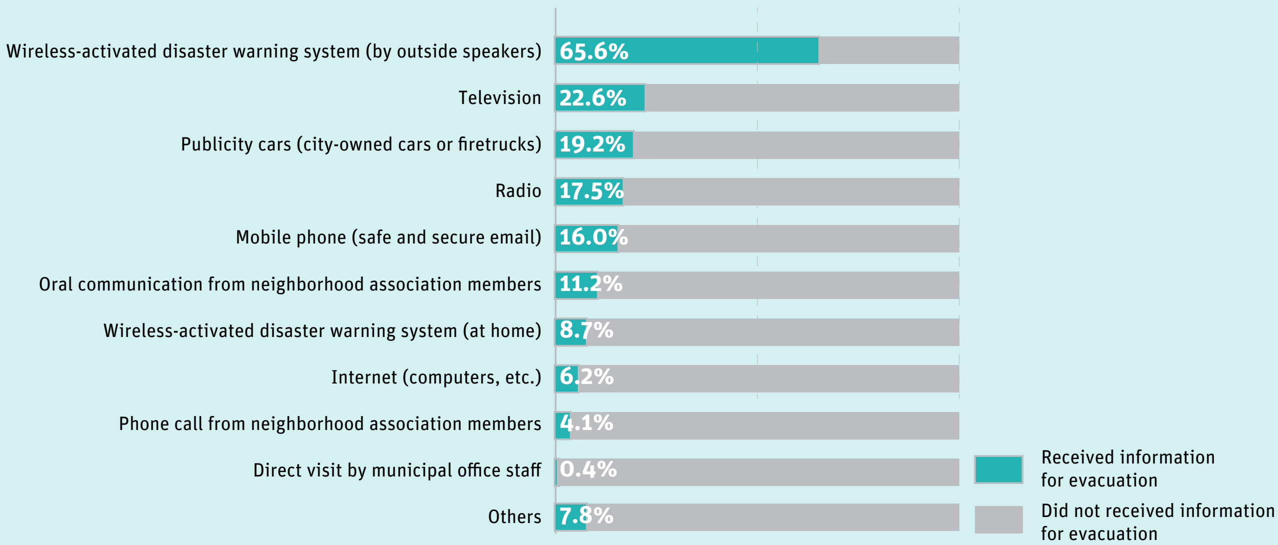
A survey conducted in 2011 found that most citizens (93.3 percent) had received evacuation information. The survey results suggest that the risk communication issues observed in 2004 had been adequately addressed **(table B9.1**).

Table B9.1: Overview of Flood Impacts in 2004 and 2011

	Total Rainfall	Casualties	Houses that Were Completely Destroyed	Houses that Required Repairs before They Were Habitable	Buildings Where Flood Reached Ground Floor	Buildings Where Flood Stayed below Ground Floor	Share of Citizens Who Received Evacuation Info (%)	# of Respondents
2004	491 mm	9	1	5,281	515	1,649	21.9	6,401
2011	959 mm	1	10	400	13	1,518	93.3	6,384

Source: Sanjo City n.d.; Sanjo City and Gumma University 2012.
Note: mm = millimeter.

Figure B9.1: Communication Channels Used to Obtain Evacuation Data—Results of Public Survey after 2011 Floods



Source: Authors' compilation based on information from Sanjo City (n.d.).

4. Lessons Learned and Key Takeaways

Over the years, Japan has developed a range of urban flood risk assessments, communication approaches, and methods that enable stakeholders to take timely and effective actions to mitigate and manage urban flood risks. Lessons learned and key takeaways from Japan's experience are as follows.

1. **Carefully consider the types and combinations of urban flood risk.** Urban flooding may involve river, surface water, and storm surge floods, singly or in combination. In Japan, many major cities, including Tokyo, Osaka, and Nagoya, are located in flood-prone lowland areas, and face a combination of flood types. The risks and impacts of urban flooding are complex and diverse, linked to key urban characteristics. Points of vulnerability depend on geographical and regional characteristics, locations and types of assets, populations' location and size, and the status of rainwater drainage facilities. Risk assessments in Japan to take into account the typology and combinations of flood risk.

   - *Assessing river flood risk:* Generally, river and surface water flood risks are defined based on their probability and the scale of possible damage. A key step in this process is to collect and organize data on rainfall, watersheds, rivers, flood areas, etc. In Japan, the standard methods of flood flow and inundation analysis use a hydraulic model of one-dimensional, quasi-two-dimensional, and two-dimensional flow processes.
   - *Assessing surface water flood risk:* If possible, it is recommended that surface water flood risk assessments be based on inundation simulations. However, depending on local geographic contexts, needs, and limitations, assessments based on historical floods and analysis of geographic conditions (elevation data and so on) are also used in Japan.
   - *Assessing storm surge flood risk:* Risk assessments for storm surge floods are conducted by running simulations based on local natural hazard risks and conditions.

2. **Clarify urban flood risk assessment objectives and parameters.** Depending on the stakeholders involved, there are various approaches, objectives, and applications that can be used to mitigate urban flood risks. It is necessary to clarify the specific purpose of the assessment, as well as how and when various stakeholders can utilize it to enhance their capacities to prepare, mitigate, and respond to urban floods. In general, risk assessments in Japan are conducted to support: (i) the planning and reviewing of structural flood risk mitigation and management measures, such as building embankments and other facilities; and (ii) the reviewing and adjusting of nonstructural flood risk mitigation and management measures, such as land use plans and evacuation plans. For example, assessments may inform land use plans of the probability of an event's occurrence (per year) and predicted level of damage (inundation depth and its extent). In Shiga Prefecture, flood risk assessments demarcate "restricted urban development areas" in order to avoid critical damage to assets and the burden of recovery. The combination of a flood risk assessment and a CBA allows planners to investigate different investment options, and how to prioritize and select investments. Efforts are being made to integrate qualitative information in the assessment of flood management investment benefits

3. **Clarify institutional roles and modes of collaboration.** In Japan, the MLIT formulates laws and guidelines that are revised whenever major disasters occur. Scientific knowledge is utilized to formulate new policies by involving researchers and academic experts. River administrators, sewerage system administrators, and mayors of municipalities at risk of inundation are responsible for risk assessments. Municipalities are also responsible for creating hazard maps and developing disaster prevention plans, based on the laws and guidelines established by the government. In terms of risk communication, municipalities, often in close collaboration with the private sector and community members, develop plans to facilitate evacuation and prevent inundation.

4. **Consider how the assessment will inform the design of structural flood management measures.**
   - *River floods:* In Japan, river administrators set the goals for river development plans and design levels for flood management based on the concepts stipulated in the River Law. The design level is calculated through statistical analyses of past hydrological data and historical rainfall. Flood simulations are conducted by river administrators to identify areas at risk of inundation.

- *Surface water floods:* Japan's national standard for flood risk management is to design and implement measures that can effectively manage a level of heavy rains likely to occur once in five years, and avoid or mitigate the inundation of assets at this level. If appropriate rainfall data are not available, similar data for large-scale rainfall in other cities may be utilized to prepare flood plans.
- *Storm surge floods:* Storm surge measures in Japan, such as coastal seawalls and embankments, are designed to withstand the highest-recorded tidal surge in history.

5. **Consider how the assessment will inform the design of non-structural flood management measures.** Flood risk assessments also inform the design and implementation of nonstructural measures to enhance people's preparedness and response to floods. Examples of good practice in Japan include the following:
   - *Critical infrastructure:* In Ozu City, flood risk communication and training demonstrate the opportunity to improve flood preparedness of critical facilities, in this case the Ozu Memorial Hospital.
   - *Evacuation plans and awareness:* Sanjo City in Niigata Prefecture used risk assessments to inform city plans for evacuation. The city prepared a guidebook for citizens with information needed for key evacuation decisions. Every household received this guidebook in 2011 to promote flood preparedness at the household and individual levels.
   - *Raising awareness of flood risk and safety measures:* In Shiga Prefecture, to enhance citizens' awareness of flood risk and safety, in addition to flood risk hazard maps, neighborhood flood safety maps were prepared to note possible areas of inundation from the overflow of small, medium, and large rivers.

6. **Prepare for predicted impacts of climate change.** There are ongoing efforts to integrate climate change considerations into flood risk assessments. Examples include the following:
   - *At the policy level,* the updated Flood Control Act highlights the need to prepare for not only the highest watermark in recorded history but also for unprecedented events.
   - *River and surface water floods:* The Floods Risk Assessment Guidelines developed by MLIT Technical Committee suggest that, to consider climate change risks, flood risk assessments should review multiple rainfall scenarios.
   - *Storm surge floods:* The current method of integrating climate change risk is to use the largest typhoons that Japan has ever experienced (approximately 1-in-1,000-year events) to identify high-risk inundation areas based on the simulation of multiple routes with the highest tide-level departure.
   - *Improving risk maps:* Cities in Japan are developing hazard maps based on flood risks and impacts from probable maximum flood strength. User-friendly maps that integrate climate change considerations include the following characteristics:
     - **i)** **Climate change risks are clearly noted**—maximum flood strength is set as a baseline.
     - **ii)** **Information is local and detailed**—maps are customized to each community and by flood type and local geographic and economic conditions.
     - **iii)** **Aids evacuation decisions**—maps inform users who, when, and where to evacuate.
     - **iv)** **Recommends actions to be taken before and after floods to enhance preparedness and response**—two sets of information are provided: one for normal (nondisaster) times, to understand the risk, and the other to refer to during evacuation in times of disaster.

7. **Improve communication efforts through various means.** In response to the extensive flood damage experienced in recent years, the country has started focusing on risk assessments and communication methods that prioritize saving lives, and thus is developing lessons and know-how to handle severe situations.
   - *Access to information:* For hazards that greatly exceed the capabilities of facilities, Japan is focusing on improving risk communication to protect lives and avoid damage. New technologies can facilitate better access to risk information. For example, the Tokyo Metropolitan Government has started using the cutting-edge MP radar, which enables detection of very subtle rainfall of 1 mm/hour. This highly accurate information is delivered to personal computers and mobile devices so that residents can prepare for floods.
   - *Risk maps and evacuation plans:* Lessons from recent floods have revealed that traditional hazard maps were underutilized by citizens during evacuation. MLIT and regional governments are improving these maps to integrate lessons learned to better help citizens decide how and when to evacuate. In addition, efforts are being made to improve the evacuation of vulnerable populations. Sanjo City, for example, supports the evacuation of those needing assistance by requiring people in need to register for additional support.

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Knowledge Note 2: Planning and Prioritizing Urban Flood Risk Management Investments

Cover Image: The Shibaura wastewater treatment plant in Minato Ward, Tokyo. This sewerage water detention facility integrates significant flood risk management functions with multipurpose urban amenities such as public green spaces, recreational facilities, and new commercial high-rises.

(Photo Credit: Kenya Endo)

1. Summary

Careful planning and prioritization are critical in the selection of an appropriate mix of integrated urban flood risk management (IUFRM) solutions. An integrated approach to urban flood risk management[1] relies on a balance of structural (including nature-based[2]) and nonstructural measures. Building on the results of flood risk assessments (as explained in **Knowledge Note 1**), decision makers utilize various tools and methodologies to suit the local context and its specific flood hazards. Some of the criteria considered in the planning and prioritization process include: the probable frequency and strength of floods, potential damage to people and property, cost-benefit analyses (CBAs), social and environmental assessments, and the capacity of existing flood risk management measures. By analyzing the decision-making processes that take place at different governance levels in Japan, this Knowledge Note illustrates how the findings and conclusions of risk assessments are translated into urban flood risk management solutions through the process of planning and prioritizing related investment. **Knowledge Note 3** will build on this information and focus on the various aspects to be considered during the design and implementation of IUFRM solutions.

In Japan, IUFRM involves collaboration and role sharing among various sectoral departments—those related to rivers, sewerage and drainage, urban development, the environment, and disaster risk management (DRM)—and stakeholders. Together with these actors, the public and private sectors, academia, community and civil society organizations, and citizens work together and share responsibilities to achieve the common goal of mitigating and managing urban flood risks in accordance with national laws, policies, plans, and guidelines. Central and local authorities carry out the following steps as part of their various **planning and prioritization processes.**

Step 1: Goal setting considers the results of flood risk assessments, including the characteristics of the region and historic floods, as well as various other factors, such as national policies and guidelines, the consistency and efficiency of existing flood management measures, progress made toward past and/or existing goals, the timing and feasibility of implementing the proposed IUFRM investments, impacts on communities, results of economic evaluation, and so on. These factors inform overall flood risk management goals (both quantitative and qualitative) and a vision for flood risk management at the city level, reflecting societal preferences including acceptable residual risk levels. Various decision-making tools are used in determining citywide goals, including those addressing uncertainty and expected climate change impacts.

Step 2: Integrated planning and prioritization processes set an operational framework for implementing citywide flood management goals. This framework outlines the specific targets and responsibilities of the various sectors that will work toward achieving these goals. The distribution of roles and responsibilities among sectors depends on various enabling and limiting factors (i.e., land availability, financial resources, time, technology, and elevation). Once the sectoral allocations and targets are determined, the respective departments strategize how to combine structural and nonstructural measures, including innovative approaches and partnerships, to achieve their flood management targets. Increasingly, nonstructural measures are gaining in importance. Tools include multistakeholder and sectoral consultations, coordination, technical evaluation and feasibility assessments, and cost-benefit analyses.

Step 3: Consensus building and responsibility sharing enable engagement and agreement regarding how to determine and implement goals by distributing responsibilities and roles among stakeholders at various stages of IUFRM investments. Building consensus between sectoral departments and citizens can be accomplished through a participatory planning process that may involve a range of activities and initiatives such as conferences, research

1 This four-part series of knowledge notes uses the definition of integrated urban flood risk management put forward by Jha, Bloch, and Lamond (2012).

2 Structural solutions include nature-based solutions—that is, "solutions inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help resilience." Green infrastructure is a type of nature-based solution defined as, "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green or blue spaces and other features in terrestrial and marine areas" (European Commission n.d.).

and development initiatives, simulations, the exchange of experts, public hearings and consultations with the public and private sector, and the use of incentives and legal regulations. In the process, public authorities from national and city governments, private sector developers and operators, community groups, and citizens—including those from vulnerable groups—discuss and define roles and responsibilities for design, construction, and operation and maintenance (O&M).

Japan's experience in IUFRM points to a number of lessons learned, organized here by the particular step involved.

Step 1: Goal Setting

- **Base goals on evidence and regularly update them.** The planning process starts with setting citywide goals for flood risk management based on risk assessments of various types of floods that each city may be vulnerable to. Per **Knowledge Note 1**, risk assessments and associated citywide flood management goals require regular review and update, reflecting changes in climate and hazard risks, urban development contexts, and available data. Based on the evidence, an acceptable level of risk in the specific context needs to be set.
- **Align local goals with national ones.** The Japanese national government leads and coordinates the process, ensuring that local-level efforts reflect the latest thinking on and approaches to integrated flood risk management. While not all cities in Japan have individual flood management plans, given the recent increase in locally concentrated heavy rain (with large economic impacts in urban areas), and the diverse range of city-level solutions available, many cities are taking the initiative to set their own flood risk management goals and associated plans.
- **Set realistic milestones aligned with long-term goals.** Cities are often compelled to set ambitious flood risk management goals in the face of increasing extreme weather events and hazard risks. However, when goals are too ambitious, achieving them becomes a challenge. In response, many cities in Japan have set long-term citywide flood management goals with specific milestones, for the short term (around 5 years), medium term (around 10 years), and long term (around 30 years) that are also segmented by sectoral targets. In general, the long-term target for enhanced rainfall drainage varies between 20 and 90 millimeters (mm)/hour, which corresponds to flood events likely to occur once every 5 to 10 years. The most common target is around 50 mm/hour.
- **Consider climate change impacts.** Amid a rise in extreme weather events, cities are increasingly aware of the need to integrate climate change risks into flood risk management plans. While integrating city-level climate change risk and impact analysis within the planning process is still rare, Japanese cities are regularly reviewing goals, as well as integrating mechanisms to prepare for unprecedented events, by placing greater focus on nonstructural life-saving measures.

Step 2: Integrated Planning and Prioritization

- **Coordinate to meet shared goals.** Interinstitutional coordination and joint responsibility for meeting shared goals is critical in Japan. Sectoral departments (such as those related to rivers, sewerage, watersheds, urban planning, the environment, and DRM) are engaged, together with the community and private stakeholders, in setting citywide flood risk management goals. Once these are established, sector-specific targets are determined, considering the strengths and weaknesses of the given measures. This allows for a coordinated approach to flood risk management without any gaps or overlaps, while maintaining flexibility in how it is adopted to best suit the city's unique urban and institutional contexts.
- **Integrate structural (including green) and nonstructural measures.** A combination of solutions is used to meet sector-specific flood risk management targets. In Japanese cities, many sectoral departments first determine the structural measures that can be implemented through national and city government initiatives. This is because flood damage occurs all over the country almost every year, and thus structural measures to protect assets and infrastructure are urgently needed. Various factors such as geographic contexts, flood hazards, land availability, financial resources, and community support determine the levels and types of structural measures that can be implemented (as also explored in **Knowledge Note 3**). Nonstructural measures may be implemented by city governments (including land use planning, zoning and regulatory instruments, flood risk communication, and awareness raising), as well as by households and communities (such as rainwater harvesting and utilization, and community-based DRM) and the private sector (such as stormwater management, including the adoption of green or nature-based approaches).

- **Set priorities based on local contexts.** Urban flood risk management plans often designate priority areas within the city where flood risks are high–for example, in Japan, underground commercial areas or transport nodes are prioritized. These areas may have suffered severe flood damage, may be watersheds of large rivers and lakes, or may have commonly high precipitation rates. Higher standards are set for these areas and they are targeted first for investments. In the design phase, these priorities are translated into tailored solutions that provide the expected level of risk protection.

Step 3: Consensus-Building and Responsibility Sharing

- **City governments can help broker partnerships.** City governments engage a wide range of stakeholders in sharing responsibility for urban flood risk management. Cities rely on, and coordinate closely with, the national government to set the policy guidelines for flood risk management and to lead large-scale river and coastal structural measures protecting against urban floods. City governments also coordinate closely with the private sector, community groups, and citizens in setting the goals and targets for urban flood risk management and also to garner support and ownership for implementation and O&M.
- **Expand the role of the private sector and community actors.** When floods strike, they can disrupt services, production, and functioning of businesses, affecting the local and national economy, and even regional and global patterns. With increasing disaster exposure, the role of private firms and community members in flood management investments is increasing in cities in Japan in line with the increasing and diversifying risks of urban floods. Along with this, cities are exploring diverse incentive mechanisms to engage and coordinate with new actors. To do so, flood risk management priorities are tackled concurrently with various other emerging priorities such as environmental sustainability, livability, and social assets.

2. Urban Flood Risk Management in Japan: Evolution and Stakeholders

2.1 The Evolution of Urban Flood Risk Management in Japan

The rapid urbanization of the 1960s and 1970s increased the impacts of urban floods in Japan. In response, the concept of coordinating river, sewerage, and watershed measures was born. In 1979, Comprehensive Flood Risk Management Measures (CFRMMs) were developed to meet the urgent needs for river improvement and runoff management in watersheds running through rapidly urbanized areas. The measures were implemented along 17 rivers. The CFRMM encouraged river management authorities (mainly from the national government) and urban development authorities (mainly from local governments) to work collaboratively to enhance cities' resilience in the face of flood risks. Although many benefits were realized, initial targets were not achieved. Only 50 percent of watershed measures and 70 percent of river measures were implemented due to rapid urbanization and budget constraints. Furthermore, the CFRMM initially focused on river floods, to the exclusion of other flood types. Also, no comprehensive measures against inundation were implemented (Research Group of Specific Urban River Innundation Measures 2004).

With increasing extreme weather events, some local governments, as administrators of sewerage systems, developed independent city-level plans for heavy rain and flood risk management to address unique hazard, geographic, and urban contexts to better protect their communities. Examples include the Tokyo Metropolitan Government's (TMG's) Basic Policy for Heavy Rain Management, Shiga Prefecture's Basic Policy for Watershed Flood Management, and Setagaya Ward's Basic Policy for Heavy Rain. These take an integrated approach that includes structural investments needed for river and sewerage management, non-infrastructure urban planning and design tools, preparedness and evacuation measures, as well as green infrastructure solutions.

Innovative efforts in the Tsurumi River Watershed in 1981 were instrumental in advancing the watershed-wide approach to flood risk management in Japan.[3] This was the first initiative in Japan to establish a watershed-wide investment plan, integrating hard infrastructure improvement measures with softer nature-based solutions such as

3 Watershed measures include storage facilities such as detention ponds and reservoirs, stormwater infiltration inlets and trenches, and permeable pavements. Although sewerage systems are involved in watershed measures, they are discussed separately.

water retention ponds and retarding basins. In 2005, the Tsurumi River Watershed was recognized by the national Act on Countermeasures against Flood Damage of Specified Rivers Running Across Cities. This advanced watershed-wide collaboration across sectors and stakeholders featured targets based on the scientific modeling of risks using historical data and climate change forecasts. Tools and approaches to promote consensus building among various stakeholders, including citizens, were also developed and utilized.

The concept of an integrated approach to flood management was further advanced through the introduction of the Specific Urban Flood Damage Measures Law (SUFDML), enacted in 2003 for eight designated rivers. This mandated that river management authorities protect urban areas and take flood management measures within and beyond each watershed. The law instructed the development of an integrated flood management plan between river and sewerage management authorities. It led to not only horizontal collaboration between national and local governments, but also lateral engagements promoting collaboration between public and private sectors. The law also defined requirements for the private sector, including the installation of stormwater storage and infiltration facilities, and collaboration with river and sewerage administrators on planning and implementing flood management measures such as water discharge, the hydraulic analysis of river and surface water floods, and the operational rules of pumping stations.

In 2013, a 100 mm/hour Safety Plan was initiated by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) to tackle the increasing impacts of concentrated heavy rain in urban areas. The plan clarifies the responsibilities of each local government department and authority, the participation of residential communities and the private sector, and flood management measures to prevent inundation in urban and residential areas. Responsibility for the safety plan is held by the local government and the public authorities for river and sewerage management. For private and public developers registered under the Safety Plan, eligibility criteria for MLIT's subsidy for stormwater storage and infiltration projects is relaxed.[4] These financial incentives help drive a multisectoral approach to urban flood risk management.

2.2 Institutional Arrangements and Key Stakeholders in Urban Flood Risk Management in Japan

IUFRM is based on collaboration and role sharing among various sectors and stakeholders. Urban floods caused by poor solid waste management are outside the scope of this study.[5] In accordance with national laws, policies, and guidelines, the departments managing rivers, drainage and sewerage, watersheds, urban planning and development, the environment, and DRM collaborate to determine and share responsibility for actions to address identified flood risks.[6] Furthermore, stakeholders such as national and local governments, the private sector, citizens, and academia work together to set and achieve shared goals for mitigating the risks and damages of urban floods. The key stakeholders involved and their roles and responsibilities for IUFRM in Japan are highlighted in **table 1**. This broad division aligns with the administrative context in Japan, as noted in **box 1**. In the following sections, this Knowledge Note focuses on examining the role of **local governments**—including at the prefecture and municipal levels—in advancing integrated flood risk management in Japan.[7]

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4 Water storage and infiltration facilities with 500 cubic meters (m^3) or more capacity are eligible for MLIT's social capital improvement grant. This threshold is relaxed to 300 m^3 for entities registered with the 100 mm/hour Safety Plan.

5 For more information, please see: TDLC on SWM and Urban Flood case study from Kitakyushu City (World Bank 2017).

6 This series of Knowledge Notes does not include information on solid waste management. For a case study related to solid waste management and urban flood risk management, please refer to World Bank (2017).

7 Watershed-level efforts led by the national government across multiple municipal boundaries are beyond the scope of this note. Therefore, the Comprehensive Flood Risk Management Measures (CFRMM) and the Specific Urban Flood Damage Measures Law (SUFDML), led by the national government, are not included.

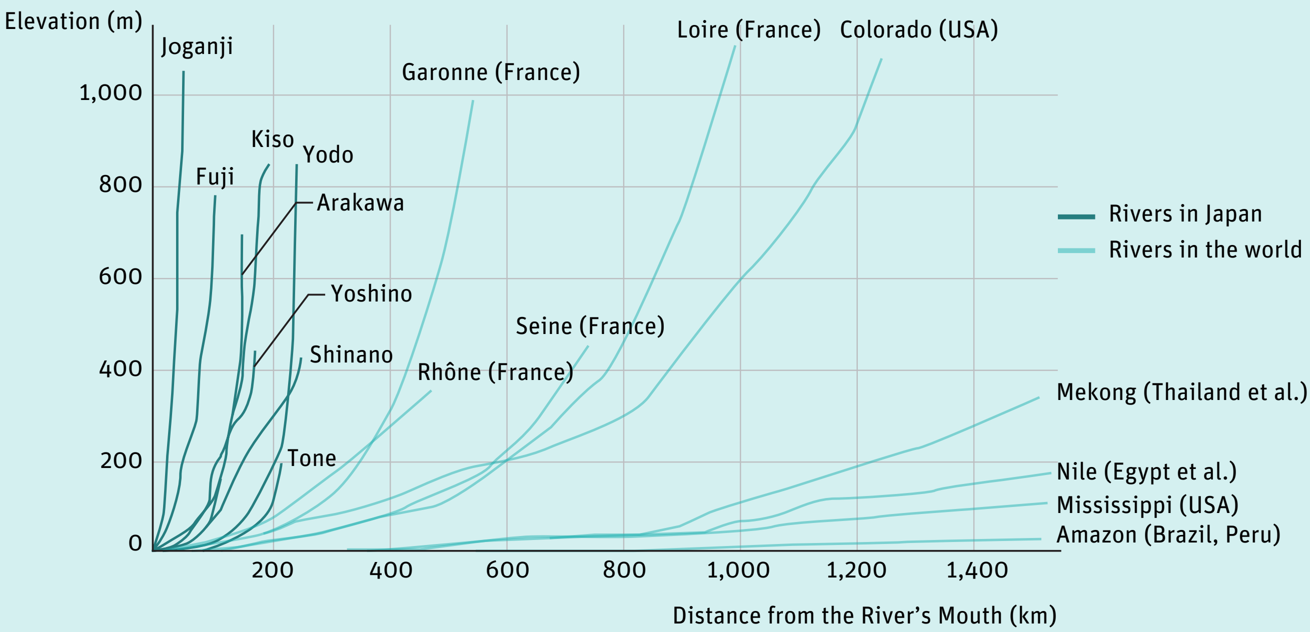
Box 1: Overview of Governance Structure and Geographical Features in Japan

The **local government system in Japan** consists of two tiers: prefectures and the municipalities that make up the prefectures. Prefectures and municipalities are both local public entities of equal status and cooperate in local administration according to their share of duties.

Prefectures are regional authorities comprising municipalities, and are in charge of broader regional administration. Japan is made up of 47 prefectures and Tokyo, governed by the Tokyo Metropolitan Government (TMG), is one of these regional authorities. **Municipalities are local public entities** that have a strong and direct relationship with local residents and handle affairs directly related to them, such as disaster risk management. As of January 1, 2015, there are 790 cities, 745 towns, and 183 villages in Japan. There are no essential differences between cities, towns, and villages in their responsibilities. A municipality with a population of 50,000 or more and meeting various other requirements is recognized as a city. In addition to ordinary local public entities such as prefectures and municipalities, there are **special local public entities** that have been established for specific objectives relating to local government. These include special wards, cooperatives, and public property districts. Tokyo's 23 special wards are, in principle, subject to the same regulations that apply to cities. The special ward system, however, has been designed to meet the distinctive needs of a large metropolis. For more information, please see http://www.metro.tokyo.jp/ENGLISH/ABOUT/STRUCTURE/structure01.htm.

Geographically, compared with other countries in the world, Japan has a large share of mountainous terrain within its small land area, which inevitably makes each river's watershed area small and its overall length short. Rivers run a short distance while the height difference from the upper to lower stream is significant. Such relatively steep rivers have fast water velocity, and this is likely to cause sudden changes in water levels downstream after heavy rain events. For more information, please see https://www.mlit.go.jp/river/pamphlet_jirei/kasen/gaiyou/panf/gaiyou2005/pdf/c1.pdf.

Figure B1.1: Selected Rivers' Elevation and Distance: An International Comparison



Source: National Institute for Land and Infrastructure Management 2004.
Note: m = meter, km = kilometer

Table 1: Sharing Responsibility for the Integrated Management of Flood Risk in Japan

Stakeholders		Major Roles and Responsibilities
Public	National Government	•Developing a basic national framework of laws, policies, programs for implementation, flood risk management targets, and technical standards; instructing and supervising implementing entities. •Developing a basic policy for river improvement plans; conducting effective and efficient improvements as the administrator of Class A rivers as stated in the River Law. •Conducting disaster risk assessment in areas under its jurisdiction; publishing and disseminating risk information. •Collecting and communicating disaster warnings and information. •Conducting disaster recovery activities promptly. •Assisting and arranging disaster prevention activities of prefectural governments and related organizations. •Establishing and enhancing flood prevention systems and organizations; advising and supervising municipal governments. •Promoting awareness of flood risk mitigation and river management.
	Prefectures	•Developing a basic prefectural framework of ordinances, programs, policies, management goals and targets in line with national guidelines; instructing and supervising implementing entities. •Developing a basic policy for river improvement plans; conducting effective and efficient improvements as the river administrator of Class B rivers. •Participating in the process of developing the national government's river improvement plans. •Developing and implementing urban planning and land use plans (that, for example, indicate where construction may be promoted, and enforce building regulations). •Installing and conducting O&M of stormwater storage and infiltration facilities in areas under their jurisdiction. •Supervising municipal governments in stormwater drainage and treatment. •In coordination with the national government, conducting disaster risk assessments in areas under their jurisdiction; publishing and disseminating risk information. •Collecting and communicating disaster warnings and information. •Conducting disaster recovery activities promptly by coordinating with national and municipal governments. •Assisting and arranging disaster prevention activities of municipal governments and related organizations. •Establishing and enhancing flood preventions systems and organizations; advising and supervising municipal governments on flood prevention. •Promoting awareness of flood risk mitigation and river management.
	Municipal Governments (cities, wards, towns, villages, etc)	•Developing a basic municipal framework of ordinances, programs, policies, management goals and targets in line with prefectural and national guidelines; instructing and supervising implementing entities. •Developing basic policy for river improvement plans; conducting effective and efficient improvements as the administrators of small rivers. •Participating in the process of developing the national and prefectural governments' river improvement plans. •Developing stormwater drainage improvement plans; conducting effective and efficient drainage improvements as the sewer administrator. •Installing and conducting O&M of stormwater storage and infiltration measures at facilities under their jurisdiction. •Aligning flood management with urban planning and land use plans. •Developing and implementing municipal master plans. •Supervising stormwater treatment in development areas. •Proceeding with watershed measures and assisting citizens. •Communicating with citizens. •Collecting and communicating disaster warnings and information. •Directing evacuation, guiding evacuees, and establishing shelters. •Developing flood response organizations and preparing emergency equipment and stocks. •Developing and distributing hazard maps. •Promoting awareness of flood risk mitigation and river management.
Academia		•Providing academic knowledge and analysis to inform tools and solutions for flood risk assessments, target setting, and standards and guidelines for investment design. •Leading discussions in committees to inform laws, policies, and standards.

Private Sector	•Understanding and cooperating in river improvement and requirements and targets for watershed measures. •Installing and conducting O&M of stormwater storage and infiltration facilities. •Conducting R&D of industrial technology on disaster prevention, damage risk mitigation, and related fields. •Investing in and installing stormwater storage and infiltration measures and promoting green infrastructure in the development sites.
Citizens	•Participating in the process of developing river improvement plans. •Understanding river improvement and watershed measures, and cooperating in the design and implementation processes. •Understanding, cooperating, and implementing household and community level stormwater management initiatives. •Leading the O&M of stormwater storage and infiltration facilities at each household and in communities. •Participating in local disaster prevention activities, including those related to urban floods.

Source: Authors' compilation.

2.3 City-Level Flood Management

In Japan, city-level flood management plans are formulated and implemented by sectoral departments in coordination with river departments to ensure the consistency of city drainage planning with river management plans.[8] Sectoral departments include those responsible for rivers, sewerage and drainage, watersheds, urban development, the environment, and DRM. The risk of storm surge floods is limited to cities located near the coasts, and landslides happen only in cities located in mountainous areas. Measures against storm surge floods, landslides, tsunamis, and typhoons are treated in different plans developed by various departments and sectors.[9] However, in local governments' DRM and preparedness plans, all flood risks mentioned above are integrated comprehensively, along with other disaster risks. This Knowledge Note focuses on the lessons learned from IUFRM planning for river floods, surface water floods, and a combination of the two.[10]

At the planning stage, flood risks are categorized by their source: river, surface water, storm surge, or multiple sources.[11] In many cases, planning is intended to tackle risks of both river and surface water floods. Policies and plans that consolidate river, sewerage, and watershed improvement measures include the Tokyo Metropolitan Government's (TMG's) Basic Policy for Heavy Rain Management, Shiga Prefecture's Basic Policy for Watershed Flood Management, and Setagaya Ward's Basic Policy for Heavy Rain.[12] A recent initiative, the **100 mm/hour Safety Plan**, actively coordinates role sharing between various local government departments as well as between civil society and private companies. Many Japanese cities have also developed sewerage or stormwater management plans in

8 The national government formulates legal frameworks (such as the Flood Prevention Act, Landslide Disaster Prevention Law, River Law, and acts involving special measures for tsunamis, earthquakes, volcanic activity, and nuclear power) and guidelines for both prefectural and city-level governments to develop specific and localized disaster prevention plans.

9 Although different prefectures and municipalities have unique organizational structures, in general, storm surge flood, tsunami, and typhoon measures are normally led by agencies and departments responsible for ports. Typhoon and earthquake predictions and preparedness are normally led by departments and units responsible for DRM and/or weather forecasting. Landslides are often led by the construction or road department's DRM division. Surface floods are often led by a sewerage management division, and river floods by river management / construction divisions (though large-scale rivers are led by MLIT).

10 This series of notes does not deal with the challenge of flash floods in depth; for a short case study, please refer to **Knowledge Note 1**.

11 Broad categories of urban flood risks are: river floods (caused by river overflow); surface water floods (caused by poor drainage of heavy rain in urban areas); and storm surge floods (caused by raised sea level due to low air pressure).

12 Cities base their independent flood management plans on several factors. Some cities are prone to surface water floods, and so cannot rely only on the national government for support managing river floods. Many of these are big cities with a high concentration of people and assets that require protection, and are led by a strong administration. In addition to the examples detailed in **box 2**, cities with independent flood risk management plans include Osaka, Yokohama, Kyoto, Fukuoka, and Sapporo.

accordance with national flood management policies. Approximately 1,400 cities, wards, towns, and villages in Japan (about 80 percent of all municipalities) have sewerage management plans, and about 900 of them also have stormwater management plans (Japan Sewage Works Association 2018).

Considering Change and Uncertainty

Changing rainfall patterns have increased the frequency of locally concentrated heavy rain, which is now one of the major causes of urban floods in Japanese cities. This is in large part due to the limited water retention and infiltration capacities of the urban landscape. For example, in July 2018, 19 prefectures and 88 municipalities in central-western Japan were severely impacted by surface water floods, largely due to concentrated heavy rain (see **table 2**). Of the 29,000 houses inundated nationwide, approximately 19,000 were due to surface water floods (see MLIT 2018a). A combination of short-term locally concentrated heavy rain, together with long-term rain that continued for multiple days, led to an overflow of surface water, exceeding sewerage and rainwater management capacity. Between June 28 and July 8, 2019 (11 days), 102 of Japan's 1,600 rainfall stations recorded a heavy maximum hourly rainfall of more than 50 mm/hour. Additionally, 189 rainfall stations observed a very high cumulative rainfall of more than 300 mm over 48 hours.

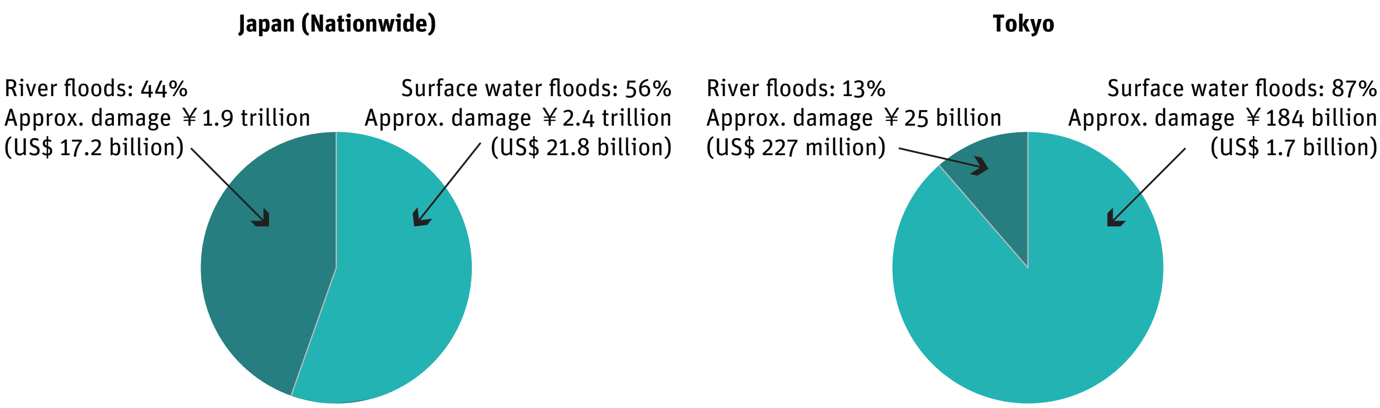
Table 2: Overview of Flood Damages Caused by Heavy Rain in July 2018

Prefecture	City	Damage (number of houses)		
		Flood above Ground Floor Level	Flood below Ground Floor Level	Total
Okayama	Okayama	1,687	3,728	5,415
Fukuoka	Kurume	423	1,011	1,434
Hiroshima	Fukuyama	751	638	1,389
...	...			
Total (88 local governments)		6,104	12,749	18,853

Source: Authors' compilation.

Improving cities' capacity to manage the risks of surface water floods is increasingly important, and local governments have a critical role to play in understanding these risks and coordinating an integrated solution. Compared with river floods, surface water floods have less impact but occur more often in Japan. And their frequency is increasing amid the rise in extremely concentrated heavy rains due to climate change. Nearly 70 percent of building damage caused by floods in Japan over the past decade is due to surface water (210,000 of the 310,000 total buildings damaged over the past 10 years) (MLIT n.d.[a]). In terms of economic damage, around 46 percent of flood damage costs in Japan, and 80 percent of flood damage costs in the Tokyo Metropolitan Area between 1993 and 2002, were due to surface water floods. **Figure 1** illustrates the economic costs of floods in Japan in general and Tokyo in specific due to surface and river floods.

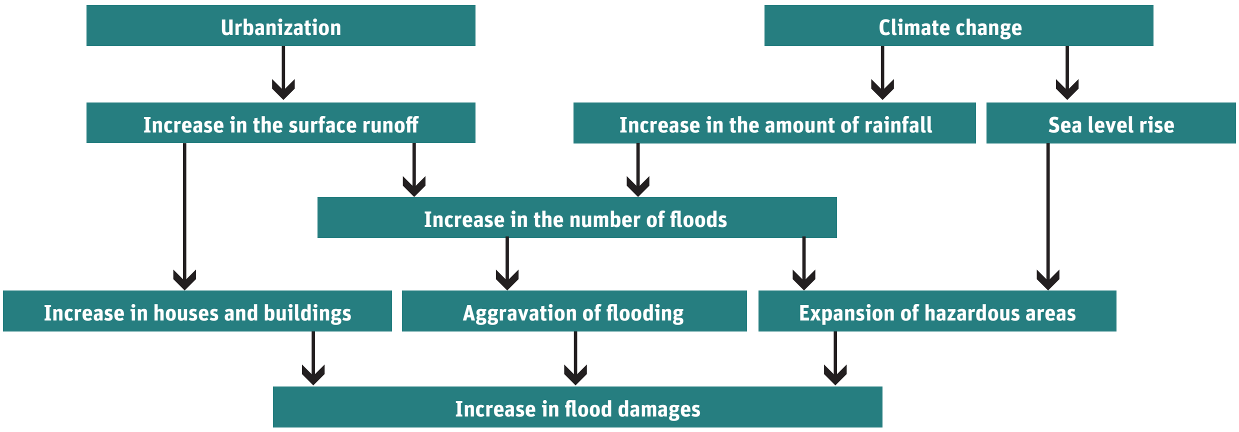
Figure 1: Share of Total Flood Damage Due to River and Surface Water Floods, 1997–2006



Source: Modified based on information from MLIT (2009).

Cities, in collaboration with the national government and research institutes, are exploring various ways to understand and integrate climate change risks within their flood management plans. Climate change impacts, combined with urbanization, can exacerbate the risks of urban floods. Climate change tends to make rainfall patterns more extreme and unpredictable, often increasing short-term (concentrated) and long-term (cumulative) rainfall. This increases the frequency of floods, especially in urban areas due to the higher occurrence of surface water runoff. As sea levels rise, vulnerable low-lying areas are increasingly exposed to flood risks (Ishiwatari 2016). **Figure 2** illustrates the interaction of these elements. By the end of the 21st century, the MLIT estimates that the amount of rainfall in Japan will be approximately 1.3 times greater, the frequency of floods about 1.4 times higher, and the probability of flood occurrence nearly 4.0 times higher than today (see **table 3**) (MLIT 2018b).[13] These climate change projections, together with recent experiences of unprecedented and extreme flood events throughout Japan, are compelling Japanese cities to further advance their flood risk plans.

Figure 2: Relationship and Effects of Climate Change, Urbanization, and Increasing Flood Damages



Source: Modified based on information from Ishiwatari (2016).

Table 3: Future Rainfall Levels, Flood Frequency, and Probability of Flood Occurrence According to Different Climate Change Scenarios

(Approximate numbers)

Assumed Climate Change Scenarios	Change in Rainfall Volume	Change in Flow Volume	Change in Flood Occurrence Probability
RCB8.5 (Equivalent to 4°C higher)	1.3 times	1.4 times	4 times
RCB2.6 (Equivalent to 2°C higher)	1.1 times	1.2 times	2 times

Source: Authors' compilation, based on MLIT (2018c).
Note: These scenarios consider the ratio of change in rainfall volume and flow volume between (i) 1951–2011 and (ii) 2090.

13 The Intergovernmental Panel on Climate Change (IPCC) forecasts climate change and evaluates environmental assessments using Representative Concentration Pathway (RCP) scenarios. RCP 8.5 is characterized by a continuous upward trend in radiative forcing after 2100. In RCP 2.5, by contrast, this would peak by 2100 and decrease thereafter.

3. Planning and Prioritizing Investments in Urban Flood Risk Management

The planning and prioritization process in Japan generally involves three key steps, detailed below.

Step 1: Goal Setting

How do Japanese cities determine the overall goals of urban flood risk management?

In Japan, urban flood risk management plans and objectives are developed in line with the national Disaster Countermeasures Basic Law (DCBL). This law clarifies the roles and responsibilities of the national, prefectural, and municipal governments, and public entities for DRM, and mandates that these entities develop and implement individual DRM plans. Citizens are also required to implement voluntary preparedness and mitigation measures under this law. Therefore, the cities' urban flood risk management goals are also set to directly contribute to the cities' mandate under the DCBL—and to work with various stakeholders to protect citizens' lives and assets and maintain public order and social welfare in the event of natural disasters, including floods.

Based on this high-level goal, specific long- and short-term targets are developed to address the unique flood risks and geographic contexts of each city. Cities often define their flood risk management targets as the level of rainfall (such as hourly maximum rainfall or return periods) they aim to manage without inundation and/or damage to citizens' lives and assets based on the results of risk assessments and flood forecasting and simulations informed by scientific data and expertise (see **Knowledge Note 1**). Japanese cities also review the damage records from the worst historical floods recorded. Additionally, ensuring coherence with national laws, directives, policies, standards, and programs is a key consideration for municipal governments as they determine their target level of risk management. City governments often put together a panel of experts from various sectors, including academia, to review technical viability, economic efficiency, social and environmental impacts, and alignment with legal and policy frameworks. For example, the goal-setting process undertaken by the Tokyo Metropolitan Area and Shiga Prefecture is summarized in **table 4**.

Table 4: Urban Flood Risk Management Goals and Decision-Making Tools and Processes in Tokyo and Shiga

	Tokyo Metropolitan Government (TMG)	Shiga Prefecture
Latest Policy	TMG Basic Policy for Heavy Rain Management (Update), 2014	Shiga Prefecture Basic Policy for Watershed Flood Management, 2012
Urban Flood Risk Management Goal	•No inundation from rainfall of up to 60(mm)/hour. •No above-floor flooding in residential areas from a 1-in-20-year rainfall (this translates to 75mm/hour in the more urbanized eastern areas and 65mm/hour in less urbanized areas, such as Tama). •No casualty caused by any rainfall, including when the amount of rainfall exceeds historical maximum target levels. •River, water, and watershed-wide disaster risk management (DRM) efforts, collectively managing up to 10 mm/hour rainfall.	•To avoid loss of lives from any type of floods (top priority). •To avoid flood damages and associated impacts to livelihoods from: -The maximum rainfall observed since World War II (equivalent to once in 50 to 100 years)—for the design of flood management measures for areas in the watersheds of large rivers[a] -1-in-10-year rainfall (50 mm/hour)—for the design of flood management measures in the watersheds of small rivers[b] -1-in-5-year to 1-in-10-year rainfall (50mm/hour)—for the design of storm-water drainage systems
Decision-making Tools & Processes	**Goals are decided through a technical committee consisting of relevant departments, academia, and public consultations attended by citizens and civil society groups.** During the revision process of the TMG's Basic Policy for Heavy Rain Management (Update), 2014, Tokyo updated its flood management goals based on recommendations from the Technical Committee, which comprised of TMG's Bureau of Urban Development (which manages urban development, watershed management, and relationships with academia), the River Management Division of the Bureau of Construction (the river administrator), and the Bureau of Sewerage (the sewerage system administrator). Consultations with citizens were conducted and views were integrated toward the finalization of the goals.	**Flood management goals within the Basic Policy for Watershed Flood Management (March 2012) were established by consultation and with inputs from:** (i) a practitioner's committee comprised of related government entities, (ii) a citizens' conference, and (iii) a technical committee comprised of academics.

Sources: Authors' compilation based on Shiga Prefecture (2012b) and TMG (2014).

[a] Rivers with a watershed area of 50 square kilometers (km^2) or more.

[b] Rivers with a watershed area of less than 50 km^2.

For cities to cope with uncertain climate change risks, having an integrated flood risk management goal that involves both structural and nonstructural approaches is critical. Cities are increasingly aware of the need to prepare for unprecedented floods that exceed the anticipated worst-case scenarios, an awareness that was heightened in 2015, when a series of large floods affected many cities in Japan. Many such cities now expect large-scale flood events whose impacts would not be fully manageable by infrastructure investments alone but would require non-infrastructural, society-wide approaches. According to one national-level guideline, "the capacity of structural measures has limits, and large-scale floods (that exceed the management capacities of infrastructure) will happen" (MLIT n.d.[b]). Therefore, the MLIT instructs cities to estimate possible inundation areas using probable maximum precipitation forecasts to develop city-level flood risk maps (MLIT 2015). This updated guidance is in accordance with the 2015 revisions to the Flood Prevention Act (Library of Congress 2015), and is based on lessons learned from the 2015 floods that exceeded the design level of existing structural measures (MLIT 2015). The range of rainfall intensities and associated management goals set in cities in Japan is summarized in **box 2**. **Knowledge Note 1** describes some of the nonstructural activities, such as climate-change informed risk mapping and evacuation planning.

Box 2: Stormwater Management Goals: Rainfall Intensity Used to Plan Sewerage Improvements

The median design rainfall intensity used for sewerage planning is around 50 millimeters (mm)/hour. The areas with rainfall intensity levels that exceed this include Okinawa, Kochi, Nagasaki, and Mie; these are regarded as heavy rain regions. Also, the following major cities have relatively high rainfall intensity levels and have set design goals above the national rainfall intensity average: Yokohama (74 mm/hour), Nagoya (60mm/hour), Osaka (60 mm/hour), and Fukuoka (79.5 mm/hour).

Source: Authors' compilation.

Step 2: Integrated Planning and Prioritization

How are flood risk management plans and priorities aligned across various sectoral departments and diverse regions?

As part of interinstitutional coordination, city planners and managers assign roles and responsibilities among relevant sectoral departments to achieve citywide goals. This distribution is based on various factors such as the city's development strategies, citywide and sectoral visions, and unique geographic contexts (proximity to a river, availability of permeable surface, etc.) and sociopolitical conditions. In the case of the Tokyo Metropolitan Government (TMG), the distribution of roles and responsibilities across departments was informed by technical feasibility and economic analyses conducted within municipal subdivisions. Based on the assigned sectoral targets, each department then develops its own investment plans, priority measures (structural and nonstructural), and schedules, according to department visions, budgets, the available range of opportunities, options and limitations (i.e., available land, etc.), and inputs from technical committees and panels. More specifically, under the citywide goal, each responsible sectoral department determines its individual runoff reduction target and forecasted rainfall levels. Based on these targets, each department then selects and prioritizes appropriate flood management measures by reviewing the technical effectiveness, economic efficiency, feasibility, and speed with which investments will have an effect. **Knowledge Note 3** provides a discussion of the specific factors and criteria considered by cities in designing and implementing IUFRM investments.

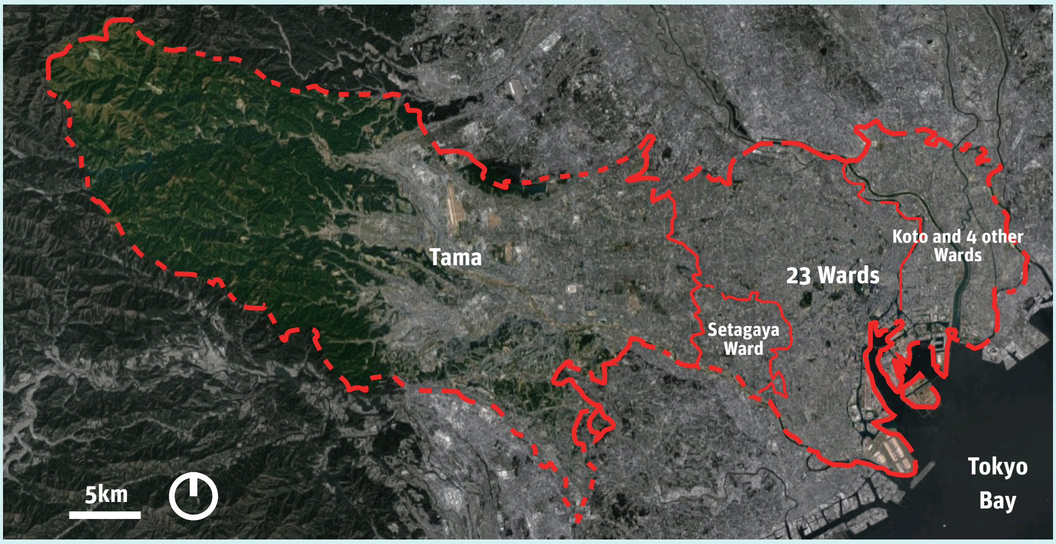
Wherever possible, departments coordinate with one another during the implementation of their flood management measures. Inter-institutional coordination extends to sequencing the construction of investments or integrating the flood risk management capacity of an investment implemented by another sector. To enhance coordination, many cities in Japan, including Tokyo, have departmental staff exchange programs, especially between the river and sewerage departments. These programs enable the interdepartmental coordination and collaboration necessary for integrated planning and prioritization through: (i) setting citywide shared goals for urban flood risk management; (ii) discussing and distributing roles and responsibilities among the relevant sectoral departments to achieve the shared goals; (iii) encouraging responsible sectoral departments to agree on their individual target runoff reduction and design rainfall levels; and (iv) encouraging departments to coordinate with one other during the implementation of their flood management measures.

Cities also prioritize certain regions or measures based on different regional flood risk contexts. For example, the Tokyo Metropolitan Area was divided into subregions based on similar geographic and rainfall patterns during the IUFRM planning and prioritization process. The process is described in **box 3.**

Box 3: Planning and Prioritizing Measures to Address Urban Floods in the Tokyo Metropolitan Area

The Tokyo Metropolitan Area can be divided into two areas based on flood susceptibility: (i) the eastern side (including the **Koto five-ward area**), which is undergoing rapid urbanization; and (ii) the western side (**Tama area**), which is relatively rich in forests and farmlands (**figure B3.1**).

Figure B3.1: Tokyo Metropolitan Area: Aerial Image



Source: Google Earth. *Note*: km = kilometer.

In the **Koto five-ward area** in East Tokyo, many neighborhoods are low lying, practically at sea level, with high ground water levels, making them susceptible to flooding. Given the geographic characteristics of the area, pumping facilities, together with enhanced flood risk preparedness and awareness-raising actions in communities, are prioritized as the most technically and economically efficient measures for the effective management of flood risks. Therefore, in this area, the sewerage and disaster risk management departments take on a large share of the responsibility for flood risk management. In locations where it is difficult to install pumping stations due to land scarcity, stormwater retention ponds are often implemented as an alternative.

The western **Tama area**, on the other hand, is characterized by high land elevation and frequent occurrence of concentrated heavy rains. Heavy rains of over 75 millimeters (mm)/hour frequently fall on small- and medium-sized rivers, including the Kanda and Shakujii rivers. Given land use restrictions, despite the need to expand urban drainage, it is impossible to widen the river channels. Therefore, the installation of retention ponds and underground storage facilities is often prioritized as the most technically and economically effective measure. Other priority measures include sewerage improvements underneath trunk lines. Given their geographic condition, neighborhoods in the Tama area also prioritize green infrastructure, an integral solution to flood risk; related efforts include conserving green spaces for infiltration and developing bioswales for temporary water retention.

In addition to prioritizing specific types of measures, Tokyo prioritizes the locations of interventions by designating “special management watersheds and districts.” These priority areas are identified based on areas with historical flood events that caused significant damage to people and livelihoods.

What tools and approaches are used for planning and prioritization?

Risk assessments (discussed in Knowledge Note 1), cost-benefit analyses (CBAs), and engagement and consensus building with communities and stakeholders inform the planning and prioritization of flood risk management investments in Japanese cities. For example, in Tokyo, the metropolitan government conducts CBAs to inform the sectoral allocation of flood risk management targets and responsibilities, as well as to compare options for flood risk management interventions within a site-specific investment project. When the TMG embarked on integrated urban flood risk management in the 1980s, a technical panel developed a report entitled "Visions for Comprehensive Flood Management in TMG (Report 61), 1986" (hereafter referred to as "Report 61"). This set a long-term citywide flood management goal of 100 mm/hour as well as an indicative allocation of targets and responsibilities between river and sewerage departments. To inform the allocations, a CBA was conducted comparing three different flood mitigation scenarios to achieve the long-term goal. These options were: (i) using conventional flood management measures such as widening river channels and expanding or bypassing sewerage pipes (river management); (ii) installing stormwater runoff management facilities such as retention ponds (sewerage management); and (iii) installing stormwater storage and infiltration facilities (watershed sewerage management). The flood management targets for the watershed and DRM departments were determined based on what was not addressed by the river and sewerage departments.[14]

Engagement and consensus building with communities and stakeholders are important steps in the planning and prioritization of flood risk management. In Japan, watershed committees discuss plans and priorities, and form agreements between the community members and the private and public stakeholders that are affected by proposed flood management plans and specific interventions. The committees often consist of relevant river and sewerage administrators, community members, and people in urban planning, housing, land property, farming, road departments, academia, and environmental and civil society organizations. TMG's consensus-building process is described in **table 4.**

How do cities decide between structural and nonstructural measures?

Cities are increasingly aware that flood risks cannot be managed effectively unless the strengths of both structural and nonstructural measures are combined to achieve their citywide flood management goals. Japan has recognized the importance of this integrated approach since the 1980s, and especially since experiencing numerous mega disasters. The Great East Japan Earthquake of 2011 highlighted the limits of relying on only structural measures,[15] as great damage occurred even in areas with high embankments. Consequently, nonstructural measures have been implemented in tandem with structural measures during the reconstruction. To prevent such damage from recurring, an embankment would have to be 30 to 40 m high (equivalent to the height of a 10-story building), which would not be acceptable from a financial, environmental, or social standpoint. In the reconstruction following the earthquake, a plan to make a mega dike (large embankment) was abandoned at an early stage. Various discussions have taken place about the construction of the embankment, as well as the acceptable level of risk to the community. In the end, the region has adopted nonstructural measures, such as prohibiting residents from living in tsunami-prone areas, relocating houses to higher ground, building evacuation centers, developing evacuation plans, and basing town restoration plans on the premise of flooding (Ishiwatari 2016).

Structural and nonstructural measures have their strengths and weaknesses, and cities must understand these to plan and prioritize such measures in an integrated manner. Structural measures, normally led by river and sewerage sectors, are often limited by geography, technical and political feasibility, construction time, and budget. In some cases, large structural investments can be modified only with difficulty, even as sticking with the original plan could in fact increase flood risk, given changes in the natural/hydrological or physical environment. On the other hand, nonstructural measures normally have much more limited flood mitigation benefits but can be adapted to a variety of risk contexts, and can respond to a changing natural or physical environment. Key nonstructural flood risk management tools and approaches considered by cities in Japan include the following:

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14 Cost-benefit analyses of various public investments in Japan, including those relevant to urban floods (such as rivers, sewerage, coastal embankments, urban planning, etc.), are consolidated in the Ministry of Internal Affairs and Communication Web Portal (in Japanese): http://www.soumu.go.jp/main_sosiki/hyouka/seisaku_n/koukyou_jigyou.html.

15 During the unprecedented earthquake, although coastal villages were protected with embankments that were 10 to 15 meters (m) high and extended around 300 km of the coastline, severe damage was caused by a tsunami that reached a maximum water level height of up to 40 m. In many places the tsunami was higher than the height of the bank, and about 190 km of the embankment collapsed. However, the embankment weakened the strength of the tsunami, which allowed citizens more time to evacuate. Areas that had good early warning and evacuation systems in place did well, while in many others, lives were lost. The incident revealed the problems of overconfidence in structural measures.

- **Water and land use management** is important in order to prepare for uncertainties such as the effects of climate change and consequent unexpected disasters. The first stage of water and land management is to protect important areas and facilities such as residential areas, roads, and power plants by river embankments. The second stage is to prohibit residents from living in vulnerable areas that cannot be protected by embankments. These areas can be used for facilities that can be shut down during a flood without negative consequences, such as sports facilities, parks, and parking lots. At the third stage, evacuation policies and approaches to empower communities for disaster prevention are planned (Ishiwatari 2016). It is important to consider flood risks in urban planning and development through building and zoning codes. Actual methods include urban planning, building codes, promoting awareness of flood risks, promoting relocation by providing risk information, and enhancing flood alert systems. In addition, there are cases where local governments establish land use policies combining road projects with efforts to improve the embankments protecting certain urban areas. Municipalities collaborate to conduct integrated projects for both flood control and land use.[16]
- **Japan's City Planning Act** regulates land use, urban facilities, and urban development projects in Japan. Existing urban areas and areas where urbanization is preferentially and systematically planned within approximately 10 years are set as Urbanization Areas. Areas where urbanization should be restricted are designated as Urbanization Control Areas. According to Article 8.2 (Ministry of Internal Affairs and Communications 2009) of the act, areas at risk of floods, tsunamis, and storm surges must not be included as priority areas for urban development over the 10-year city planning period.
- **Building Standard Law and Urban Planning Law and Ordinance.** According to the Building Standard Law (Ministry of Internal Affairs and Communications 2018), local governments can designate areas as vulnerable to disasters such as floods, tsunamis, and storm surges. The ordinance also allows local governments to prohibit construction of residential buildings in vulnerable areas and to set other development restrictions for disaster prevention. In some cases, this is specifically to reduce stormwater runoff (as shown in cases 1 and 10 of **Knowledge Note 3**). The case of Shiga Prefecture's land use regulation and water-resistant architecture (see section 3.2 of this Knowledge Note) is a representative example. Although these land use and architectural regulations may be difficult to apply in already developed areas, national efforts to do so are underway. For example, the MLIT established the Location Optimization Plan in August 2014 to foster the formation of compact and resilient cities by attracting development to areas with low flood risks through siting public facilities and amenities strategically (MLIT n.d.[c]). The plan excludes high-risk, flood-prone areas from public investments aimed to enhance livability, while focusing the implementation of flood management measures—including river and sewerage management facilities, stormwater detention and infiltration facilities, and public alert evacuation systems—in high-risk zones.
- **Disaster risk reduction and management.** Promotion of residents' awareness of flood risks through strengthening disaster risk reduction and management is also a key nonstructural measure. This is done through the public dissemination of flood risk information to enhance evacuation and early warning, as well as by encouraging residents to adopt voluntary flood prevention methods, such as using water-resistant building methods. Real estate transactions require the disclosure of flood risk information (see section 3.2 for Shiga Prefecture's regulation) and local ordinances require that real estate agents be kept up to date on the latest flood risk information in areas such as Kyoto Prefecture.

As part of the urban flood risk investment planning and prioritization process, many cities in Japan first define the scope and scale of structural flood management investments that cities can implement during the planning period. They then determine the types and levels of nonstructural measures that are necessary to complement the structural investments so as to achieve the city's flood risk management goal, although increasingly, the consideration of structural and nonstructural investments is taking place in parallel. Considering the time required for investment design, consensus building, construction, and financing of structural measures, TMG's Basic Policy for Heavy Rain Management (Update), 2014, illustrates the city's plan to achieve the long-term goal of managing 100 mm/hour

16 City development in Japan is governed under the City Planning Act. Comprehensive strategies for urban development in designated area are planned, implemented and monitored. Zones are classified as either Urbanization Areas (also called Urbanization Promotion Areas) or Urbanization Control Areas. Urbanization Areas are already urbanized or should be systematically urbanized with high priority within the ten years, under associated land use and building code regulations, etc., that promote development. In Urbanization Control Areas, urbanization is controlled and limited in principle, and therefore, very little public infrastructure investments are made in these zones. For more information, see: https://www.mlit.go.jp/common/000997836.pdf and https://jica-net-library.jica.go.jp/library/jn334/UrbanPlanningSystem_all.pdf.

rainfall by a combination of structural and nonstructural measures over a 30-year period (see section 3.1).

In addition, the city's flood risk investment planning and prioritization process are complemented by other, related urban policies and plans. As part of their DRM and climate change adaptation strategies, Japanese cities are increasingly putting strong emphasis on nonstructural measures as the first line of defense to protect lives and livelihoods in the face of unexpected disasters. While they are relatively low cost and adaptable, the challenge of nonstructural measures, however, is the need for long-term and consistent engagement, awareness raising, and training that fits the needs of the specific social and environmental contexts of each community and stakeholder group. Experiences of the 2018 flood events in Japan reaffirmed the importance, as well as the challenges, of nonstructural flood management measures. In Mabi City, Okayama Prefecture, several lives were lost in an area where citizens were informed of the high flood risks. Most casualties were elderly citizens who were unable to evacuate in a timely manner, largely as a result of failure to receive flood warnings, lack of awareness and recognition of the risk levels, as well as limited means to safely move to shelters. This experience demonstrates that in order to save lives under unprecedented flood events, structural measures alone may be insufficient. Furthermore, to enhance nonstructural measure such as effective evacuation, significant efforts are required to not only communicate risk information but also to strengthen the capacity and knowledge of response and evacuation actions. **Knowledge Note 1** provides further information about outreach, communication, and evacuation activities led by Japanese cities.

Step 3: Consensus Building and Responsibility Sharing

How can cities build consensus and share responsibilities with various stakeholders by engaging them in the process of planning and prioritizing flood management investments?

Through the planning and prioritization process, cities actively engage the national government, local community, and private firms in order to not only build consensus on the proposed flood management investments, but also to garner support in sharing responsibilities for the implementation steps to follow, such as design and construction, financing, and O&M. Table 5 illustrates how the roles of various stakeholders are diversifying in planning, prioritizing, and implementing flood management investments in Japan, based on different flood risk types.

Cities in Japan rely on, and coordinate with, the national government to lead large-scale river and coastal structural measures against urban floods. Additionally, cities are supported by the national ministry, the MLIT, which provides guidance related to domestic laws, technical guidelines, expertise, and financial resources required for implementing structural measures for minor rivers, sewers, and drainage, as well as nonstructural measures, such as risk maps and early flood warning and evacuation systems. While being aware of unique regional contexts, the MLIT also plays a crucial role in ensuring the consistency of flood management measures across various local governments as it monitors their effectiveness and promotes an integrated approach. The national government supports local governments, which often have limited capacity and resources to plan, prioritize, and implement flood management investments independently.

Table 5: Major Stakeholders and Role Sharing, by Type of Flood Risk

Type of Flood Risk	Examples of Flood Management Measures	Key Stakeholders Engaged by Local Governments in Investment Planning and Prioritization
River flood	River improvement (levees)	MLIT (financing and standards); Local community (consensus building)
	Reservoirs / parks	Local community (consensus building, design, O&M); Private firms (design, construction, financing, O&M of facilities)
Surface water flood	Sewerage system improvement	MLIT (financing and standards);
	Underground cisterns	MLIT (standards); Public schools (construction of facilities, O&M); Private firms (design, construction, financing, O&M of facilities)
	Rainwater harvesting systems	Private firms (design, construction, financing, O&M of facilities); Community and households (consensus building, design, construction, financing, O&M of facilities)
	Water retention / detention ponds	MLIT (standards); Private firms (design, construction, financing, O&M of facilities)
	Green infrastructure	Local community and households (consensus building, design, construction, financing, O&M of facilities); Private firms (design, construction, financing, O&M of facilities)
Storm surge flood	Sea walls	MLIT (financing and standards); Private firms (implementation of codes, financing, including public-private partnership)
Combined / all flood	Early warning and evacuation	MLIT (standards); Local community (consensus building, awareness, implementation)
	Land use plans, zoning and building codes	MLIT (standards); Local community and households (consensus building and implementation); Private firms (design, construction, financing, O&M of facilities)

Source: Authors' compilation.

Private firms and communities are making greater investments in flood management to meet the increasing and diversifying risks of urban floods. While flood risks in urban areas continue to increase beyond a level that the public sector alone can manage, private firms and residents face significant economic and social costs due to increasing risks of inundation. With increasing costs facing also the private sector, new methods of actively engaging private firms and community are emerging, with new stakeholders playing roles in the design, implementation, financing, and O&M of flood management investments. Individual households and communities also play a significant role in implementing their own flood management measures, such as by installing stormwater storage tanks. Such a bottom-up approach can help build consensus among residents and communities and raise public awareness of flood risk management. Innovative ways of implementing, operating, and maintaining urban flood risk management measures are further detailed in **Knowledge Notes 3** and **4**.

4. Case Studies

This section offers three case studies of how IUFRM planning and prioritization are implemented by local governments in Japan. Key features and lessons learned are outlined below.

The case of TMG involves a highly concentrated population, set of assets, and economic activity. TMG's IUFRM approach shows how ambitious cityside flood risk management goals are set, together with sectoral targets and both structural and nonstructural measures, through a coordinated approach.

Shiga Prefecture is an example of a midsized city with a moderately concentrated population, set of assets, and economic activity. Its IUFRM approach highlights progressive land use planning and building codes.

Setagaya Ward,[17] the largest local government in TMG by population, is a residential and commercial area that has relatively abundant green space but is facing increasing urban flood risks due to development pressures. Setagaya's IUFRM approach is characterized by an active, bottom-up community-led approach, with wide application of green infrastructure solutions promoted not only as flood management measures but also as furthering urban and community development and environmental conservation.

4.1 Case of Tokyo Metropolitan Government

Context

Importance of IUFRM in TMG

While geographical differences exist across its subdivisions, the TMG area overall is highly exposed to many devastating floods from heavy rain. Tokyo can be divided into: (i) the eastern central ward areas, and (ii) the western Tama area. Around 90 percent of the land in the eastern wards has been urbanized, compared with between 30 and 80 percent in Tama, where land is primarily used for agriculture and forestry. Due to rapid urbanization, agricultural and forestry areas are disappearing rapidly throughout the city, especially in the eastern ward areas. As a result, stormwater in the city does not infiltrate into the ground; instead it flows into rivers and sewerage systems, thereby leading to frequent floods from overflow caused by concentrated heavy rains.

Tokyo has been increasingly experiencing heavy rains of over 50 mm/hour, and this recent trend is expected to continue due to climate change and the urban heat island phenomenon. Heavy rains are unevenly concentrated in the western parts of the central ward area and the Tama area. Especially, heavy rains of over 75 mm/hour frequently occur along small- and medium-sized rivers, including the Kanda and Shakujii rivers. Since the mid-1980s, small- and medium-sized rivers and sewerage systems have been improved (often widened) to be able to manage 50 mm/hour of rainfall, resulting in a significant decrease in flood damage. Since these changes, there have been no cases of floods damaging more than 10,000 buildings; however, once every few years, there are still floods that affect over 6,000 buildings and are a serious concern to the residents and businesses of TMG.

In September 2005, the western wards of the city experienced heavy rains of 100 mm/hour. Eight rivers flooded, including the Kanda and Shakujii rivers, and 5,827 buildings were damaged. Other recent incidences of urban flooding in Tokyo include: damage to approximately 300 buildings in Machida City in August 2008; to about 800 buildings in the Itabashi and Kita wards in July 2010; and to about 500 buildings in the Setagaya and Meguro

17 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.).

wards in July 2013.

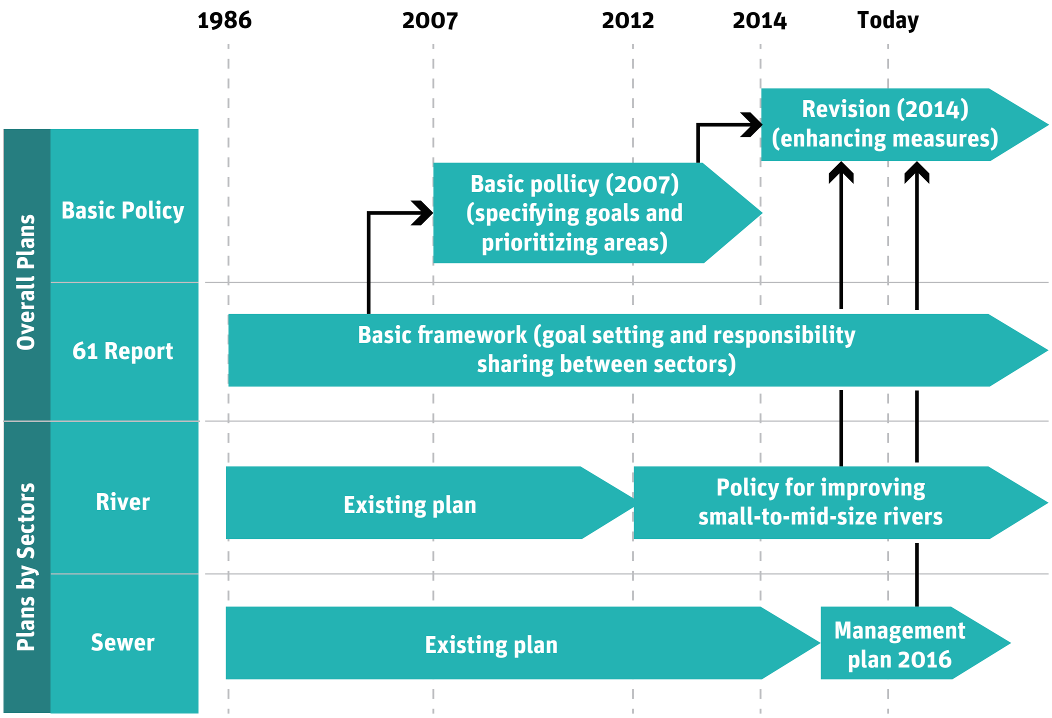
The potential economic and social impacts of inundation from a large-scale flood are immense; such a flood could disrupt key infrastructure and impair economic, social, and political functions at a citywide, national, and potentially global scale (MLIT 2017). For example, large-scale floods in Tokyo could damage or delay transportation infrastructure, leading to difficulties for commuters, as well as disruption to lifeline utilities (such as water, gas, power, and communication infrastructure), which could have a significant knock-on effect on business operations and homes. Recent studies (Japan Society of Civil Engineering 2018a) have estimated that total damages to assets and economic activities from a large-scale flood[18] in Tokyo could add up to an estimated ¥100 trillion (approximately $909 billion[19]), and in Tokyo's Arakawa district alone could be over ¥60 trillion ($545 billion), affecting 1.26 million people (Japan Society of Civil Engineers 2018b). Therefore, there is a strong economic and social case to be made for TMG to advance its capacity to manage floods.

In the light of this, TMG has been pioneering efforts to integrate flood risk management measures into its urban development strategy. These efforts include (i) close coordination and alignment with both national economic development policies and the city's urban development policies; and (ii) engagement of various sectors and stakeholders to facilitate a comprehensive approach to the planning and prioritizing of flood management investments.

Evolution of IUFRM Planning in TMG

TMG initiated its IUFRM efforts in 1986, and these have since evolved in stages, as illustrated in **figure 3** and detailed below.

Figure 3: Timeline of Plans for Managing the Risk of Heavy Rain in Tokyo



Source: Authors' compilation based on interviews with TMG authorities (Furuki 2018).

18 A 1-in-1,000-year river flood.
19 This and the figure that follows are based on an exchange rate of ¥110 = $1 (2018 average).

Visions for Comprehensive Flood Management in TMG (1986)

In the 1980s, TMG was experiencing frequent floods, exacerbated by urbanization. The national government had recently launched a general watershed management policy. TMG started discussions on flood damage mitigation in 1983 and compiled the results in the "Visions for Comprehensive Flood Management in TMG: Report 61 to the Governor of Tokyo," published in July 1986.

This report set TMG's citywide flood management target at 100 mm/hour, among other short-, medium-, and long-term goals; set general sectoral role-sharing targets to achieve this citywide goal between river, sewerage, watershed, and urban planning and development sectors; detailed the watershed management measures that the city would take; and set the general urban flood (or heavy rain) management planning and investment framework for the city. The report also established four stages of the river and sewerage management planning process: (i) reviewing an existing plan, (ii) drafting a tentative plan, (iii) developing a long-term plan, and (iv) establishing a basic timeline/phasing plan.

Policy for Managing Heavy Rains in Tokyo (2007)

In August 2007, TMG redefined heavy rain measures by releasing the Tokyo Basic Policy for Heavy Rain Management. The policy adopted the citywide flood management goals and sectoral role sharing targets of Report 61. Through this process, nonstructural measures were integrated as critical measures for urban flood risk management, as the implementation of the planned structural measures were facing delays due to difficulties in land acquisition and time-consuming coordination. The policy set a phased timeline of 10 years and a long-term outlook of 30 years, specifying priority areas (mainly river watersheds, sewerage watersheds, and underground facilities).

Guidance and Directions for Small and Medium Rivers in Tokyo (2012)

In response to a flood caused by heavy rains in 2008, TMG released the "Guidance and Directions for Small and Medium River Improvements in Tokyo" in November 2012. The report incorporates findings presented by an expert committee concerning "the state of future maintenance in small and medium rivers in Tokyo." The report pointed out the urgent need to consider local rainfall characteristics when enhancing the flood management goals for Tokyo's small- and medium-sized rivers. Based on this guidance, the methodology for flood management in Tokyo was updated, by setting individual targets based on observed historical rainfall.

Tokyo Sewerage Management Plan (2013, 2016)

In 1994, the sewerage system covered 100 percent of the population (9 million in 2013) in the central ward areas of TMG, and 99 percent of the population (4.16 million in 2013) in the Tama area (Bureau of Sewerage, TMG 2014). Tokyo's sewerage system comprised approximately 16,000 km of sewer pipes, 20 wastewater treatment plants, and 86 pumping stations as of 2016, when the Tokyo Sewerage Management Plan was prepared. Despite this extensive investment and coverage, new operation and management methodologies, including asset management, are needed to maintain the rapidly aging sewerage facilities so that they can effectively manage continued urban development and increasing disaster risks due to climate changes. The 2016 management plan is the city's latest five-year basic policy to enhance sewerage system management and address issues such as the renewal of sewerage pipes and facilities and inundation mitigation.

Updated Policy for Heavy Rain Management (June 2014)

In response to the increasing frequency of extreme weather events and concentrated heavy rain, TMG updated the Tokyo Basic Policy for Heavy Rain Management in 2014 to further strengthen the city's urban flood risk management capacity through promoting **role sharing between public and private sectors**.[20] The plan was updated based on consultations and engagement of various stakeholders including citizens, academia, the private sector, and various city departments. The process was coordinated by a special interagency committee on heavy rain led by representatives from TMG's Bureau of Urban Development (urban development and watershed measures), Bureau of Construction (river administration), and Bureau of Sewerage (sewerage administration).

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20 The updated policy encouraged the participation of the private sector and community members to implement flood management investments in urban areas by incentivizing the installation of rainwater harvesting and detention facilities in private commercial and housing development projects as well as enhancing the rainwater infiltration capacities of green spaces. Large-scale underground shopping centers and metro companies, in collaboration with the public sector, were to enhance their flood management and emergency preparedness and response plans.

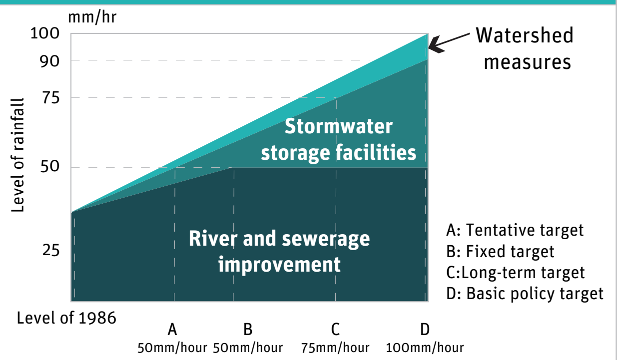
It further **elaborates long-term (approximately 30-year) targets** by adopting **area-specific targets** based on rainfall probability (once in 20 years). It considers local rainfall characteristics, utilizing microclimate and geographical information, especially in the central ward area and Tama area of TMG. It also designates priority areas and elaborates on the **measures to be implemented in these areas** based on the frequency and severity of historical flood damages—mainly river watersheds, sewerage watersheds, and underground facilities. It enhances flood preparedness in targeted urban centers such as large-scale underground shopping malls. It details short- to medium-term investment priorities, including plans for the 2020 Tokyo Olympics and Paralympic Games as well as until 2024 (the 10-year plan).

Step 1: Goal Setting

TMG's IUFRM goals have evolved over time since their initial establishment in 1984. The goal-setting process is revisited every 10 to 20 years and is expected to continue evolving to adapt to the urban development context as well as to changing climate and disaster risks.

While the citywide flood management goal for TMG remains **100 mm/hour,** in Report 61 this overall goal was revisited and refined through efforts to accelerate and actualize progress toward it by setting short-, medium- (10-year), and long-term (30-year) goals. **Table 6** lists the goals and targets of TMG's three key policy frameworks.

Table 6: Evolution of Tokyo's Flood Management Goals

<table>
<tr><th colspan="2">A Vision for Comprehensive Flood Management in TMG: Report 61 to the Governor of Tokyo (1986)</th></tr>
<tr><th colspan="2">Flood Management Goals & Targets</th></tr>
<tr><td>• City-wide flood management target: set at 100mm/hour, based on rainfall likely to occur once in a few hundred years
• Combined flood management target for river and sewerage improvement: to effectively manage (without overflow / flood) 50mm/hour rainfall
• Underground rivers, storage reservoirs, and under ground facilities: to collectively handle rainfall of 40mm/hour
• Watershed measures: to manage rainfall of 10mm/hour</td><td>
</td></tr>
<tr><th colspan="2">Tokyo Basic Policy for Heavy Rain Management (2007)</th></tr>
<tr><th colspan="2">Flood Management Goals & Targets</th></tr>
<tr><td>10-year target (in priority area):
• Preventing above-floor inundation by promoting installation of water reservoirs and sewer and river overflow facilities
• Saving lives under historical maximum level of rainfall through enhancing evacuation</td><td>Long-term (approximately 30 years) (entire TMG):
• Preventing any floods from rainfall up to 60mm/hour
• Preventing above-floor inundation from rainfall up to 75 mm/hour by promoting installation of water reservoirs and sewer and river overflow facilities and water retention facilities within housing and urban development
• Saving lives under historical maximum level of rainfall through enhancing evacuation</td></tr>
<tr><th colspan="2">Plan : Updated Tokyo Basic Policy for Heavy Rain Management (June 2014)</th></tr>
<tr><th colspan="2">Flood Management Goals & Targets</th></tr>
<tr><td colspan="2">Long-term (approximately 30 years) (entire TMG):
• Preventing above-floor inundation from rainfall events with up to 1-in-20-year probability (75mm/hour in central ward area and 65 mm/hour in Tama area)
• Preventing any inundation throughout TMG from 60mm/ hour rainfall
• No casualty at any rainfall level, including those in excess of historical maximum target levels</td></tr>
</table>

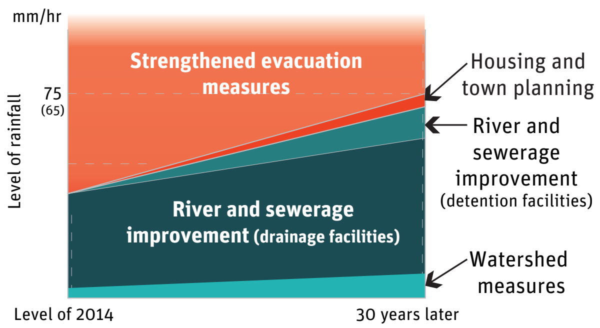
Sources: Authors' compilation based on TMG (1986, 2014).

Step 2: Integrated Planning and Prioritization

Planning

Under the citywide flood management goal, TMG integrates both structural and nonstructural measures for flood risk management to be implemented by various sectoral departments and stakeholders. The sectoral allocation was determined by various factors, including available land, time, technology, and finance through a CBA, which was conducted when determining the sectoral allocation under Report 61. Each sectoral department then reviews and determines various tools and approaches to fulfill its sectoral flood management targets. **Figure 4** describes the sectoral allocation of flood management targets within the Updated Tokyo Basic Policy for Heavy Rain Management (2014).

Figure 4: Heavy Rain Management Goals and Sectoral Allocation in Tokyo

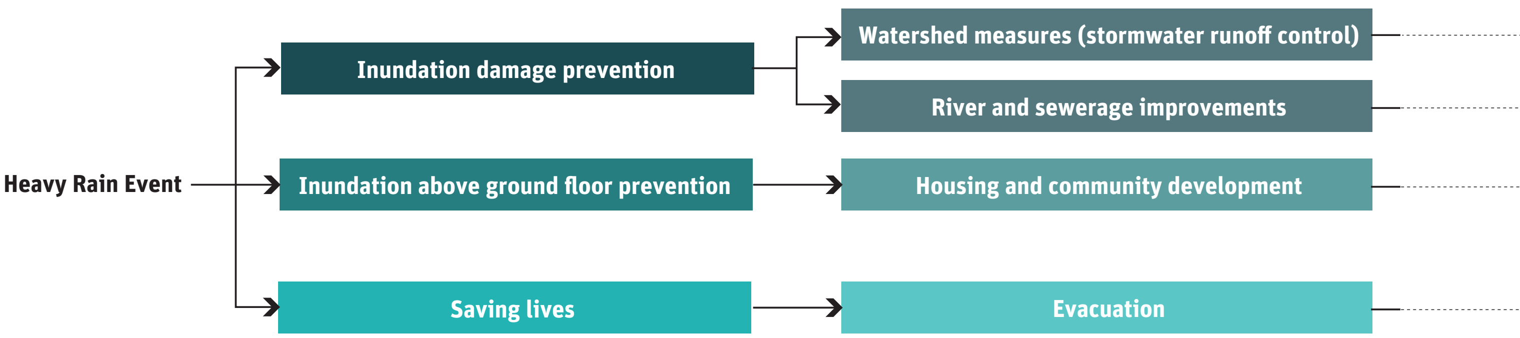


Source: Modified based on the Tokyo Basic Policy for Heavy Rain Management (updated June 2014).

Prioritization

In TMG, prioritization of flood management measures takes place within, and not between, sectors. To meet the shared citywide flood management goals, sectoral targets are determined based on various factors (as described above). Within each sector, various options for flood risk management are reviewed and prioritized. The Updated Tokyo Basic Policy for Heavy Rain Management includes sector-specific structural and nonstructural measures (included in **figure 5**).

Figure 5: Types of Heavy Rain Measures Identified in the Tokyo Basic Policy for Heavy Rain Management (updated 2014)



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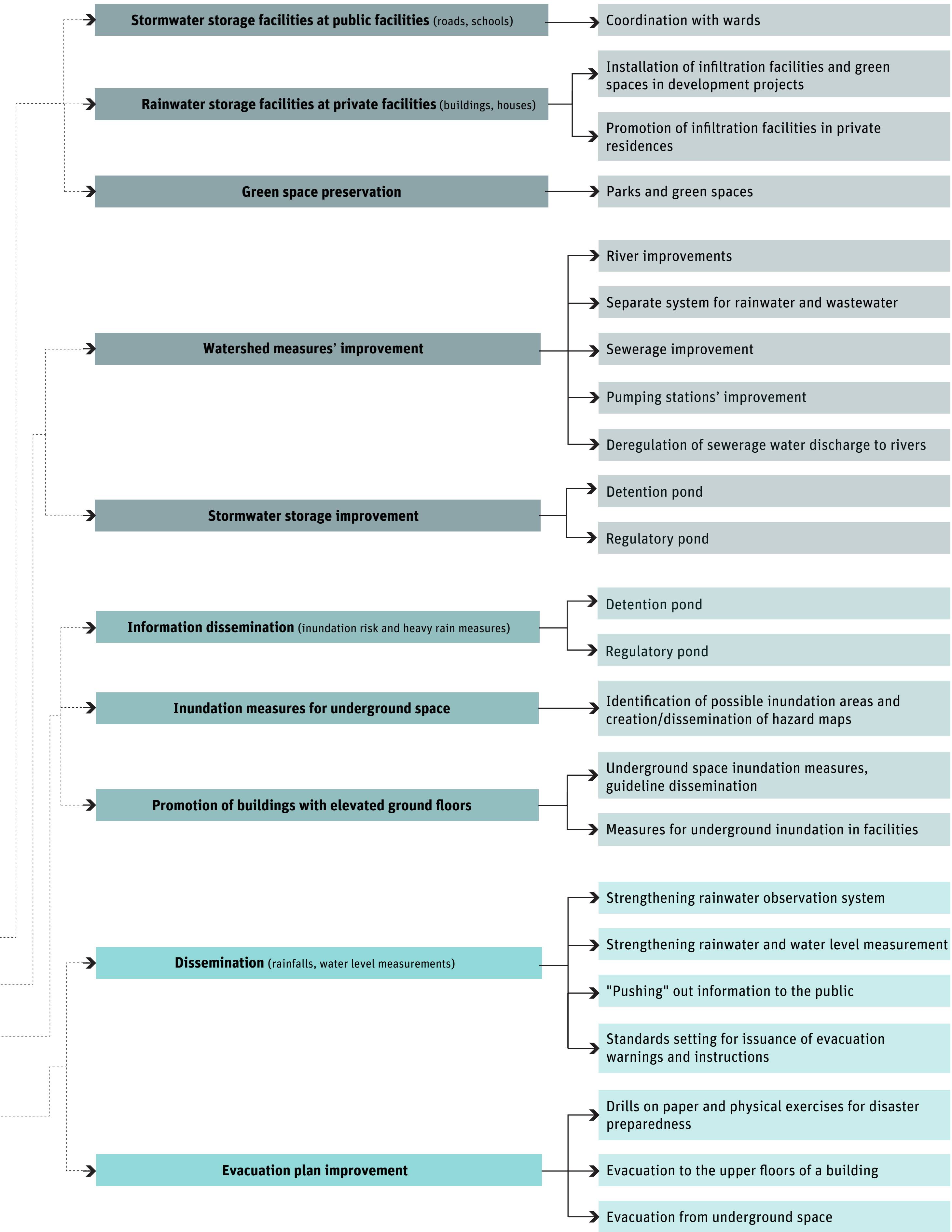
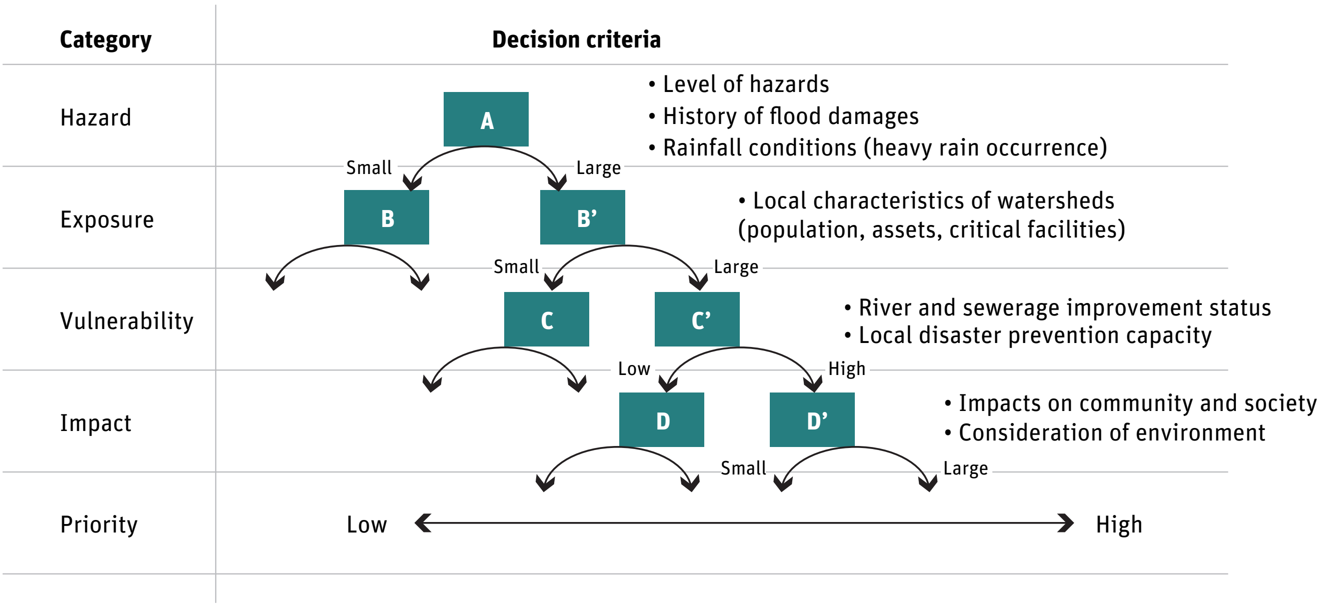


Source: Modified based on information from TMG (2014).

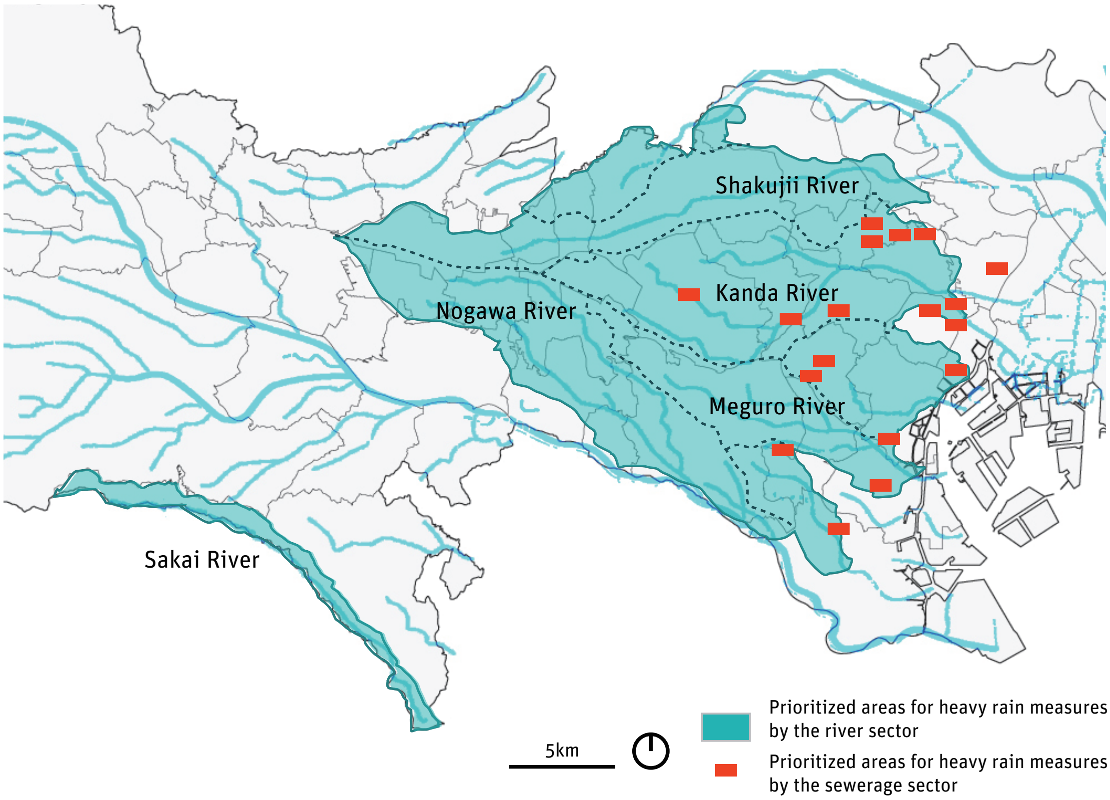
TMG also sets priority intervention areas based on various considerations regarding exposure and vulnerability to flood risks, such as historical data on past flood damage, forecasts of future damage, the population and assets in the watershed, maintenance status of rivers and sewerage systems, impact of flood management measures, and impact of floods on the region (**figure 6**). The identification of these areas also depends on sectoral approaches. In case of the sewerage sector, based on the characteristics of flood damage and rainfall, the areas that suffer from substantial flood damage are designated as "watersheds and districts targeted for intensified measures." **Figure 7** shows the combined prioritized areas for heavy rain measures designated by the river sector and by the sewerage sector. In Tokyo, surface water floods are caused by short-term heavy rain. Generally, the prioritized areas show similar rainfall trends and are concentrated in regions that have frequently experienced rainfall of over 50 mm/hour in the past.

Figure 6: Criteria for Designating Priority Areas for Flood Risk Management in Tokyo



Source: Authors' compilation.

Figure 7: Watersheds and Districts Prioritized for Intensified Heavy Rain Measures in Tokyo, 2014



Source: Modified based on information from TMG (2014).
Note: km = kilometer.

In Tokyo, risk assessments and damage estimations simulate simultaneous river and surface water floods. Priority areas are set based on the outcome of the simulation and a CBA. Efforts in the prioritized watersheds and districts are then managed through a joint river and sewerage committee (Furuki 2018). Although the river and sewerage systems are managed by different public entities in Tokyo, an integrated approach—using a joint simulation and a joint selection of prioritized areas—makes efforts toward achieving the common goal of reducing urban flood risks and damages more efficient and effective.

Step 3: Consensus Building and Responsibility Sharing

As flood management goals have evolved over time to be more specific to local contexts, the process of goal setting in TMG has also progressed to engage various stakeholders. While revising the Basic Policy for Heavy Rain Management in 2014, consultations took place with various departments, wards, academia, river and sewerage facility operators, private sector actors, and citizens. For example, the need to set more ambitious targets based on not only past rainfall patterns but future rainfall projections in the face of climate change was one point of feedback received from the general public. The TMG Heavy Rain Management Committee—comprised of university professors, lawyers, and representatives from TMG's urban planning, construction (in charge of rivers), and sewerage departments—reviewed, responded to, and integrated these feedback points into goal-setting processes wherever possible (TMG 2014).

Along with building consensus to develop a common citywide goal for flood risk management, TMG has also been developing and implementing various programs that designate responsibility for flood management across a range of sectors and stakeholders. These efforts include the development of guidance and policies by river and sewerage departments that are promoting self-help efforts and mutual assistance among citizens, providing financial incentives and grants, supporting new technology development, and gathering and sharing risk information to promote effective evacuation.

Additionally, TMG has developed and implemented various measures that foster intersectoral consensus building. Cooperation between the river and sewerage departments increased significantly, especially after the 2005 heavy rain of over 100 mm/hour in the Suginami and Nakano wards, which highlighted the need for cooperation to manage extreme heavy rain events. These intersectoral consensus-building mechanisms include: (i) having joint meetings regularly between the river and sewerage sectors to share updates and methodologies for risk assessment and planning; (ii) conducting flood risk modeling and simulations jointly for rivers and sewerage sectors, and integrating risks from both river and surface water floods; and (iii) periodic personnel exchange and secondment arrangements between river and sewerage departments.

Citizens also participate not only in the planning process but also in sharing the responsibility for mitigating urban flood risks. The roles of citizens and communities as a whole are also increasing amid growing awareness about the importance of nonstructural measures for urban flood risk management, such as individual- and household-level preparedness and evacuation. (Various ways in which citizens design, implement, monitor, and maintain various flood management investments are described in **Knowledge Notes 3** and **4**.)

Future Challenges

In light of Tokyo's continued urban development, coupled with increasing and changing flood risks, along with a rapidly aging flood management infrastructure, TMG will need to revisit its flood management plans and priorities approximately every 10–20 years and continue to adapt to the new urban flood risk management challenges the city faces. Current and future challenges that Tokyo faces in planning and prioritization are: (i) further analyzing the risks and setting targets for flood risk management at the watershed level; (ii) enhancing the stakeholder engagement and coordination mechanisms to scale planning and implementation of flood management measures; (iii) communicating and raising awareness regarding flood risks, preparedness, and evacuation with citizens; (iv) monitoring progress against plans and targets on a continuous basis; and (v) utilizing the latest technologies (risk models, etc.) to enhance flood risk planning.

To address these challenges, partnerships and coordination with additional departments and stakeholders will be important. Related efforts might include integrating flood management perspectives within the city's plans, and acting to support environmental sustainability, biodiversity management, parks and recreation, and climate change mitigation and adaptation. Furthermore, scaling and diversifying the methods and areas for engaging new stakeholders—particularly citizens, communities, and the private sector—is critical, as the budget and human resources for implementation and O&M of structural measures for flood management will continue to increase. Therefore, Tokyo, like other local governments in Japan, is exploring new ways to involve not only the public sector but also the private sector and citizens.

4.2 Case of Shiga Prefecture

Context

Importance of IUFRM in Shiga Prefecture

Shiga Prefecture has experienced serious flood damages over the last decade due to its geographical and topographical characteristics and abundant water resources, coupled with climate change and uncontrolled urban development. Shiga is renowned for its rich water resources, including Lake Biwa, the largest freshwater lake in Japan. Nearly 120 rivers (most of them less than 50 km in length) flow into the lake, each of which has tributaries and streams that cover the entire prefecture. Plains stretch out around the lake, and are surrounded by watersheds. The narrow and steep terrain characteristics and the large volume of sediment that flows into the rivers and raises the river beds further increases the risks of floods and droughts.

Despite its vulnerability to water-related disasters, urban planning and development in Shiga Prefecture historically took place without much consideration of flood risks. As a result, forested areas and rice paddies with water retention functions, as well as natural levees and vegetated areas for infiltration, were degraded or lost due to urban development pressures. With climate change, concentrated heavy rain as well as powerful typhoons threaten to increase the risk of floods in Shiga's urban areas.

These combined effects of geography, urban development, and climate change have resulted in significant flood damages over the past decade in Shiga Prefecture. For example, in 2008, Nagahama City was affected by concentrated heavy rain of more than 84 mm/hour, which inundated more than 11 households and commercial buildings above floor level, and 203 buildings below floor level (Shiga Prefecture 2012a). In 2013, Typhoon Man-yi, with a maximum hourly rainfall of 78 mm, caused one death, nine injuries, 49 above-floor and 497 below-floor level inundations, and damage to more than 1,500 hectares of agricultural land from both river and surface water floods (Shiga Prefecture 2014b, 2012a).

In light of this situation, in 2012 Shiga Prefecture developed the Basic Policy for Watershed Flood Management and in 2014 established an Ordinance on Promotion of Watershed Flood Management in Shiga Prefecture (Shiga Prefecture 2015) as an effort to mitigate urban flood risks. These enhanced the understanding and integration of flood risk management in the urban planning and development process.

Step 1: Goal Setting

The policy and ordinance set forth Shiga Prefecture's flood management goals and approaches. These include targets for both structural and nonstructural measures to manage flood risk. Related responsibilities are shared among all stakeholders—including individual households (self-help), communities (mutual assistance), and the government (public assistance). Two key flood management goals are to:[21]

1) **Save lives**—prevent inundation of more than 3 meters above floor level, and damages to houses from a 1-in-200-year rainfall level
2) **Avoid damages that disrupt the quick recovery and continuation of livelihoods**—prevent above-floor-level inundation from a 1-in-10-year rainfall level.

Shiga Prefecture's four key flood management approaches have the following objectives:

1) **Drain**: Use river channel flood control measures and flood control facilities such as dams to safely drain flood water down rivers and sewerage systems.
2) **Store**: Implement watershed storage measures to mitigate stormwater runoff. Relevant watershed resources include retention ponds, ground and soil in forests, paddy fields, and reservoirs.
3) **Contain**: Reduce overflow by containing water inside the watershed. Measures to mitigate damage in floodplains include the use of circle levees, double levees, open levees, forests, land use regulations, and flood-resistant construction.
4) **Prepare**: Enhance disaster preparedness through awareness raising efforts, disaster prevention drills, dissemination of disaster information, early warning systems, and risk assessments; and strengthen disaster responses such as evacuation and flood control activities.

For efforts to **drain** water, numerical targets are set for river and sewerage management interventions at the national minimum level. These consist of:

- River management and improvement interventions that seek to prepare relatively large rivers (with watershed areas larger than 50 km^2) for rainfall equivalent to the largest historical flood since World War II (an approximately **1-in-30-year rainfall level**).
- River management and improvement interventions that seek to prepare relatively small rivers (with watershed areas less than 50 km^2) for a **1-in-10-year rainfall** level (around 50 mm/hour).

21 A once in 10-year rainfall level is equivalent to approximately 50 millimeters [mm]/hour, a 1-in-100-year rainfall is approximately 109 mm/hour, and a 1-in-200-year is approximately 131 mm/hour (Shiga Prefecture 2018a).

- Sewerage management and improvement interventions that seek to prepare urban sewerage systems for a **1-in -5 to 10-year rainfall** level (around 50 mm/hour).

Additionally, through efforts to **store**, **contain**, and **prepare**, Shiga Prefecture aims to achieve the two goals of avoiding loss of lives (top priority) and damages that disrupt quick recovery and continuation of livelihoods in the face of any kind of rainfall (defined as a **1-in-200-year rainfall** level) through watershed-wide interventions.

Step 2: Integrated Planning and Prioritization

Planning

Watershed flood management measures in Shiga Prefecture are comprised of draining, storing, containing, and preparing. In alignment with the two key goals noted earlier, clear roles and responsibilities are specified for each stakeholder to promote flood management measures (**table 7**).

Table 7: Sharing Responsibility for the Installation and Maintenance of Stormwater Storage and Infiltration Facilities

Stakeholder	Role	Responsibilities
Prefectural government	Main body	• Installation and maintenance of stormwater storage facility and underground infiltration facility • Supervision of stormwater drainage in development areas of Class A rivers
City and municipal government	Main body	• Installation and maintenance of stormwater storage facility and underground infiltration facility • Supervision of stormwater drainage in development areas of Class B rivers
	Support	• General support for household-level flood control measures
Residents	Main body	• Installation and maintenance of stormwater storage facilities and underground infiltration facilities in residential houses
Private operators	Main body	• Installation and maintenance of stormwater storage facilities and underground infiltration facilities in commercial buildings

Source: Authors' compilation.

For watershed flood management in Shiga Prefecture, the river, sewerage, and watershed sectors cooperate and share responsibilities related to urban flood management under the common goal of reducing flood risks and damages in cities. Additionally, each stakeholder from the public, private, and industrial sectors cooperates, coordinates, and shares responsibilities to ensure an integrated approach.

Prioritization

Watershed-level measures in Shiga Prefecture are not prioritized across sectors, as are river and sewerage maintenance efforts, but are instead prioritized within each sector. Shiga Prefecture manages 506 rivers, which are ranked from Class A to D based on the level of need for emergency improvement. Among them, 85 rivers are Class A, and 42 rivers are Class B. The factors considered in order to prioritize and determine flood management measures include: the level of risk (degree of damage); characteristics of rivers (watershed size, presence of a raised bed, embankment, or excavation); level of emergency risk (history of flood damage, assessment of flood risks in the area); risk to human life (based on an assessment of the terrain and of the proximity and condition of residences); and impact on assets (based on an assessment of potential damage and reconstruction). The factors considered when deciding the efficiency of measures include their impact on local businesses and on regional development. Last, enabling environments needed for IUFRM investment are also considered; these include local demand for flood management assistance and statements of intent to cooperate in flood risk management investments and activities.

Additionally, Shiga Prefecture prioritizes several nonstructural measures for flood risk management. These include:

(i) Neighborhood safety assessments to inform and encourage citizens' flood preparedness activities

Collaboration between the government and local community is crucial to raise awareness of flood risk management, implement structural and nonstructural measures, and encourage the participation of residents. Shiga Prefecture has investigated the safety of different geographic areas in the local watershed and identified high-risk areas based on citizens' lifestyles. To estimate what is called the "neighborhood safety level," flood risk is assessed not only along rivers but also in waterways and nearby facilities. The maximum flood depth is determined using an inundation simulation at the maximum possible flood scale (1-in-1,000-year flood). Through its website, the prefecture provides flood risk information through neighborhood safety maps for each municipality (see **Knowledge Note 1** for details).

(ii) Land use planning and requirements for flood-resilient construction in high-risk areas

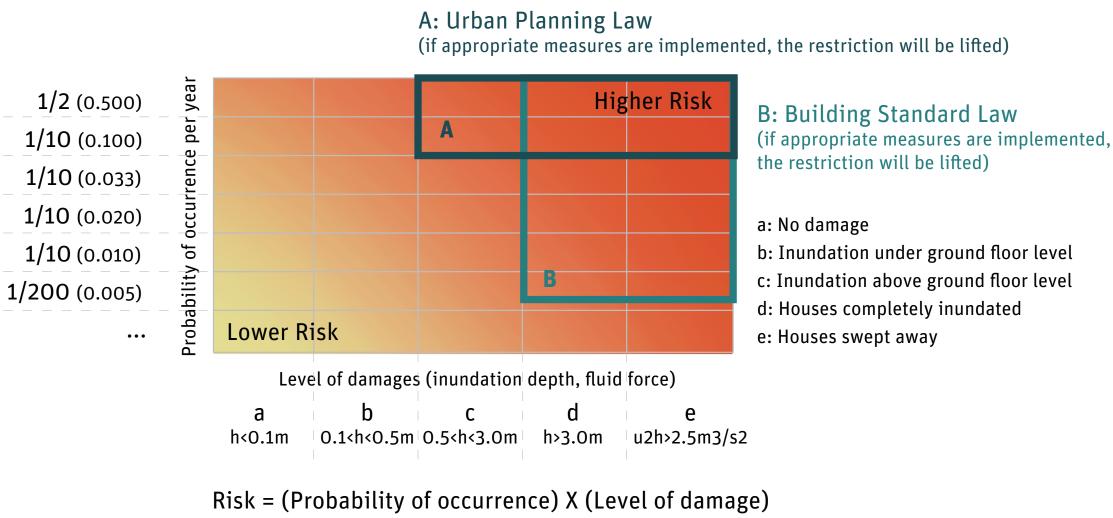
Shiga Prefecture's earlier urban development and land use plans did not take flood risk into consideration since quantitative assessments were not available at the time. Therefore, the prefecture has since revised land use regulations and requirements for construction based on the identification of high-risk areas from risk assessment results. These regulations ensure that higher standards of flood risk management measures are implemented in high-flood-risk areas. Article 39 of the Building Standard Law (Shiga Prefecture 2015; MLIT 2007) requires that:

- Areas where the inundation of houses is expected are regulated as high-flood-risk areas.
- The construction of public facilities such as hospitals, schools, government agencies, residential buildings, and so on, is essentially prohibited within high-flood-risk areas.
- Construction in high-risk areas is allowed only if safety measures for residents are implemented.

Areas within Shiga Prefecture are assigned to two flood risk categories (Shiga Prefecture 2015) (**figure 8**):

- In **Area A**, flooding above the ground-floor level frequently occurs and "urban development is limited to avoid critical damage to assets and increased burden of recovery" (Shiga Prefecture 2015). If there are a number of floods above the ground-floor level, it will lead to critical damage of assets and make reconstruction difficult. In Shiga Prefecture, river and sewerage improvements have successfully coped with floods caused by a 1-in-10-year rainfall (50 mm/hour) or more.
- In **Area B**, construction is restricted to avoid damage and loss of life. The prefecture has prioritized the protection of the lives of its citizens and actively works toward the prevention of all flood damage. Based on the flood strength of a 1-in-200-year probability and the design scale of the Yodo River, the prefecture designates areas with life-threatening risks of inundation and loss of houses as "districts with construction regulations," where the prefectural government sets certain criteria for approval related to construction. Buildings in the regulated areas must have evacuation floors above the possible height of inundation and stronger structures so that the buildings will "not be swept away by strong fluid force" (Taki 2018).

Figure 8: Integrating Flood Risk Assessments into Land Use Plans, Shiga Prefecture



Source: Modified based on information from Shiga Prefecture (2015).

Step 3: Consensus Building and Responsibility Sharing

Shiga Prefecture has played a central role in IUFRM planning, specifically with regards to setting common goals across sectors and establishing the Basic Policy for Watershed Flood Management. Shiga Prefecture has been actively promoting river and sewerage improvement, setting guidance and policies, providing assistance and subsidies, establishing technological standards, and providing appropriate flood risk information.

Its legally binding policy promotes consensus building and the implementation of watershed flood management measures. This policy has two broad purposes: (i) to clarify the responsibilities of local governments, businesses, and residents and establish the legal groundwork for a watershed flood management plan; and (ii), by enforcing these policies, to protect residents' lives, health, and properties from flood damage.

The Shiga Basic Policy for Watershed Flood Management incorporates public opinions through a Watershed Flood Control Committee, known as a "residents' committee." Generally, 10 committee members from a variety of backgrounds such as academia, relevant divisions of public authorities, and residential areas are selected. In addition, the committee invites other experts. The committee studies flood management issues and develops policy recommendations. The committee clarifies residents' roles and responsibilities based on consultation and consensus building with the residents themselves.

In IUFRM planning, businesses form consensus by understanding and cooperating in plans and policies for installing stormwater storage and infiltration facilities in private facilities and large-scale developments. To encourage and enhance these measures, Shiga Prefecture leverages an incentive and assistance system. Residents participate in the policy-making process through the Watershed Flood Management Committee, which serves as a mechanism to promote consensus building.

Furthermore, the government established the Department for Watershed Flood Management Policy. Shiga Prefecture and other regions in Japan clearly define the responsibilities and duties of each participating organization according to the legal system, and the administrator of each sector cannot take measures beyond its authority or jurisdiction. In the past, Japan had not established a separate watershed authority despite the existence of river and sewerage administrators. The new department collaborates with a range of stakeholders and aims to promote comprehensive watershed flood management across the region.

Future Challenges

Shiga Prefecture sets neighborhood safety levels in innovative ways. Land use regulations and requirements for flood-resilient construction in high-risk areas, which are a major focus of the basic policy, have established a new precedent. In the rest of Japan, high-flood-risk areas are identified based on historic flood damages. However, Shiga Prefecture's designation is based on estimated future flood risks, the first such example in Japan's history.

The redevelopment of existing houses is required under the regulations for flood-resilient construction in high-flood-risk areas. This raises the importance of consensus building among residents in targeted areas. Currently, in Shiga Prefecture, 50 areas that have residential buildings or are expected to plan developments are eligible for Area A classification. However, out of these cases, only two (Shiga Prefecture 2018b) have been designated as Area A.

In an effort to address the risks posed by the area's many rivers with raised beds, the Shiga Basic Policy for Watershed Flood Management estimates where houses could be inundated or swept away. Such areas might expect a certain level of fluid force, which led the prefectural government to consider restricting the construction of buildings. However, there is currently no sufficient scientific evidence of the impact of fluid force to buildings. Therefore, the "map of fluid force" is used merely as a reference, along with other maps indicating flood risk and safety, not as a criterion for high-flood-risk areas. Shiga Prefecture plans to make fluid force a criterion for high-flood-risk areas when sufficient scientific evidence is gained (Shiga Prefecture 2014a). However, gathering such evidence remains a challenge.

4.3 Case of Setagaya Ward

Context

Importance of IUFRM in Setagaya Ward

Source: Google Earth.
Note: km = kilometer.

Setagaya Ward is the most populated special ward[22] in Tokyo and is located at the southwestern corner of the TMG. Though higher in elevation and with more agricultural land and green spaces compared with eastern Tokyo, due to rapid housing development, Setagaya's dense urban fabric has significantly reduced its capacities to infiltrate, absorb, and store rainwater over the years.

With the intensity and uncertainty of rainfall increasing due to climate change, Setagaya has experienced various urban floods in recent years. In September 2005, torrential rain affected Tokyo and brought over 100 mm/hour of rainfall to the area. The stormwater runoff from rivers and sewerage systems inundated 221 houses above floor level, and 245 houses experienced basement flooding. Similarly, in 2013, multiple rainfall events exceeded 60 mm/hour, with many households affected by above-floor-level and basement flooding.

In light of this context, in 2009, the ward developed the Setagaya Ward Basic Policy for Heavy Rain (updated in 2016) and the Setagaya Ward Heavy Rain Measures Action Plan (updated in 2018) to strengthen flood prevention and protection measures. They share the overall goal of the TMG Basic Policy for Heavy Rain Management, while complementing it with specific targets and measures to be implemented at the ward level for IUFRM. They elaborate on how the ward and TMG coordinate and share responsibilities to protect the lives and assets of Setagaya's residents during floods.

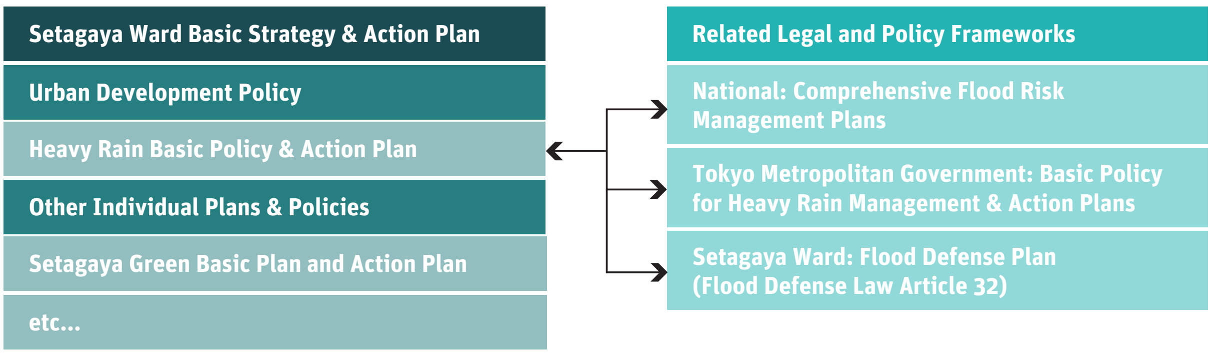
22 Setagaya Ward was home to approximately 909,000 people as of March 2019 (http://www.city.setagaya.lg.jp/kurashi/107/157/692/694/1888/d00121945.html).

Setagaya's policy and action plan for heavy rain were developed through a multistakeholder and citizen-led process, which took a unique approach to integrating various nature-based solutions for rainwater harvesting and management, as well as community-based solutions for increased flood risk awareness and preparedness. These complement infrastructural measures to improve river embankments and drainage.

Step 1: Goal Setting

The Setagaya Ward Basic Policy for Heavy Rain and Setagaya Ward Heavy Rain Measures Action Plan adopts the TMG's overall flood management goal, and clearly define how the ward's overall visions, plans, and legal frameworks link to other relevant policy frameworks (see figure 9). The Setagaya Ward Basic Policy for Heavy Rain was established as a sectoral policy under the Setagaya Ward Urban Development Policy, which is a key policy under the Setagaya Ward Basic Strategy and Action Plan. In close coordination with the national-, TMG-, and ward-level legal and policy frameworks, the Setagaya Ward Heavy Rain Measures Action Plan outlines the ward's specific measures to deliver goals with multiple priorities at various levels.

Figure 9: How Setagaya Ward's Heavy Rain Basic Policy and Action Plan Connects with Other Legal and Policy Frameworks



Source: Authors' compilation.

As part of TMG's Basic Policy for Heavy Rain Management and Action Plan, Setagaya Ward is a priority area for flood risk management given its geographic location within high-risk watersheds. Therefore, Setagaya Ward's goals are fully in line with TMG's targets for high-priority watersheds:

- **10-year goal:** to prevent flood damage during heavy rain of 55 mm/hour as much as possible. If a historic maximum rainfall were to occur, the ward aims to focus on protecting the lives of its residents.
- **30-year goal:** to prevent any flood damage from heavy rain of 60 mm/hour; and, second, to prevent inundation above floor level by rainfall of approximately 75 mm/hour in the ward area and 65 mm/hour in the Tama area. For rainfall that exceeds these levels, the policy seeks to focus on preventing casualties.

Additionally, the ward sets out three key principles:

1) **Living with rain.** This centers on an awareness of the importance of understanding and communicating the risks of heavy rain, river levels, and potential floods to inform and encourage citizens' own disaster mitigation, preparedness, and evacuation actions at the household and neighborhood levels.
2) **Storing rain.** This focuses on the importance of public and private investments in the installation of water storage facilities to retain or delay the flow of rainwater into urban drainage systems and thus avoid overflow.
3) **Utilizing rain.** This centers on the importance of restoring collected rainwater back into the ground, as well as recycling water for toilets, for the watering of plants, and as backup storage in case of an emergency.

Step 2: Integrated Planning and Prioritization

Planning

In full alignment with TMG's policies and action plans for flood risk management, the shared but differentiated roles and targets of the various sectors have been defined within Setagaya Ward's heavy rain policy and action plan. The four key sectoral approaches are:

1) Improving river and sewerage systems
2) Promoting infiltration, retention, storage, and utilization of stormwater as watershed-based flood management measures
3) Developing housing and neighborhoods so as to reduce inundation from floods
4) Saving lives through enhancing evacuation measures

Overall, river and sewerage management are led by TMG, in close coordination with the ward's responsible departments. On the other hand, "green" (nature-based) and nonstructural measures and targets for watershed management, saving lives, and evacuation are led mainly by Setagaya Ward and its various stakeholders. Setagaya's sector-based flood management targets are illustrated below.

River and Sewerage System Improvement

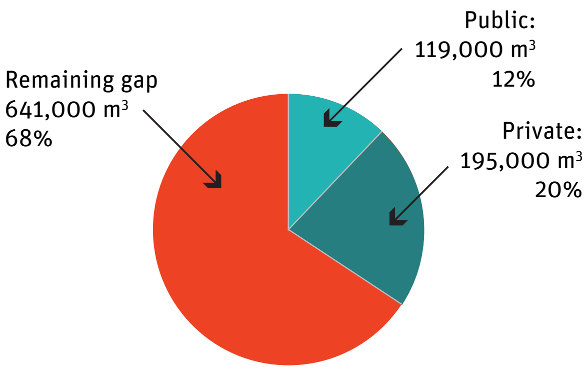
- **River.** Collaborating closely with TMG, Setagaya Ward aims to manage rainfall by river improvement measures, such as river drainage interventions (widening of channels, and so on) and retention ponds along the watersheds, to prevent above-floor inundation from rainfall of **75 mm/hour in the ward area** and **65 mm/hour in the Tama area**. In particular, Setagaya Ward, in close partnership with TMG, is prioritizing interventions along rivers without capacity for 50 mm/hour rainfall management.
- **Sewerage.** Collaborating with TMG, Setagaya Ward aims to manage rainfall of **50 mm/hour** by using sewer pipes and stormwater storage facilities, as well as avoid casualties caused by inundation in watershed areas by rainfall of 60 mm/hour.

Watershed-Based Flood Management Measures

- **10-year goal** (by 2021): to improve capacity to tackle a total of **480,000 m^3** of rainfall, the equivalent of **5 mm/hour** by promoting efficient infiltration, retention, storage, and utilization of stormwater.
- **30-year goal** (long-term goal): to manage approximately **960,000 m^3**, or the equivalent of **10 mm/hour** of rainfall, by promoting efficient infiltration, retention, storage, and utilization of rainwater/stormwater.

Since 1975, Setagaya Ward has been working with its residents and businesses to install rainwater harvesting, storage, and stormwater infiltration facilities throughout the city. As a result, as of March 2015, the ward-wide rain and stormwater management capacity achieved through these investments was reported as approximately **310,000 m^3**. New 10- and 30-year targets were also set, in line with TMG's target of achieving **600 m^3/ha** of rain and stormwater management. Setagaya Ward's achievements against proposed targets are illustrated in **figure 10**. A community-based rainwater harvesting campaign promotes household and community participation, which is described in **box 4**.

Figure 10: Setagaya Ward's Progress toward Watershed-based Flood Management Targets



Source: Authors' compilation based on Setagaya Ward (2016).

Box 4: Community Based Rainwater Harvesting Campaign in Setagaya

In response to increasing torrential rain and inundation damage, Setagaya Ward leaders and residents gathered to launch a campaign called **"Let's build a Setagaya dam together."** It is estimated that if each household in Setagaya installs a 300-liter stormwater retention tank, the collective retention volume of stormwater would be approximately 140,000 tons (or m^3), the equivalent of a small-scale dam in Japan.

The ward established a subsidy program in 2007, providing financial support up to 50 percent of the cost of both tank and construction fees, up to a maximum of ¥35,000 (approximately $318), to encourage the installation of small tanks by households. As of 2013, 384 cases were funded and 65,974 liters of rainwater harvesting tanks were installed for residents' nonpotable water usage, such as for irrigating garden plants and washing cars. Local residents and communities lead the O&M of the rainwater harvesting and storage systems installed in their businesses and in households.
Source: Authors' compilation based on information from Setagaya Ward (2015a).

Figure B4.1: Rainwater harvesting tanks installed in Setagaya Ward

Source: Setagaya Ward 2018b.

In order to fill the remaining gap, Setagaya Ward actively promotes "green" infrastructure as a major approach toward strengthening watershed management, focusing on measures that store, filter, and minimize runoff of stormwater. Setagaya Ward defines green infrastructure as "infrastructure and a way of thinking that promote stormwater storage and infiltration, flood prevention, water purification and use of underground water by effectively using functions possessed by nature such as green land and water" (Setagaya Ward 2018a). Through advancing green infrastructure, Setagaya Ward also aims to create an attractive living environment. Therefore, the promotion of green infrastructure in Setagaya furthers the goals of both flood and watershed management and urban design and development. Additionally, green infrastructure measures are also promoted through Setagaya's environmental plan, the Setagaya Green Basic Plan and Action Plan (Setagaya Ward 2015b). This plan highlights the value and importance of urban green spaces involving temples, houses, forests, watersheds, and agricultural land, and promotes the preservation of green spaces for water circulation, as well as to store and infiltrate stormwater.

To promote green infrastructure, Setagaya Ward is undertaking several awareness raising, capacity building, and cross-sectoral partnership efforts. Specific green infrastructure actions promoted through the basic policy are as follows.

Introducing the concept of green infrastructure through promoting:
- Residents' awareness of the importance of green infrastructure in watershed measures through pamphlets and other media
- The creation of "rain gardens" for storage and infiltration of stormwater from drainpipes at small-scale private facilities and existing houses

Advancing green infrastructure through public sector initiatives such as:
- Preservation and installation of green spaces or parks, or renovation of existing parks as well as development of new facilities and renovation of existing facilities managed by Setagaya Ward, Tokyo, and the national government
- Installation of green streets (streets that allow stormwater drainage from the sides of the roads and infiltration through planted zones) following the construction of new roads and renovation and maintenance of existing roads

Promoting engagement and implementation of green infrastructure by the private sector and households through:
- Installing "rain gardens" and "rainwater planters"[23] at public and private facilities for stormwater infiltration
- Requesting local landowners and managers to install stormwater storage and infiltration facilities

Monitoring, reporting, and assessing the performance of green infrastructure through:
- Quantifying the capacity of stormwater storage and infiltration systems such as green spaces

Implementing adequate maintenance and operations through:
- Inspection and cleaning of installed green infrastructure
- Cooperating with the related departments of the ward government to promote the preservation and installation of green space

Prioritization

Furthermore, Setagaya Ward's heavy rain basic policy and action plan prioritize the promotion of flood risk management, especially through green and nonstructural measures in vulnerable locations, public spaces, and buildings and private homes. These measures are a priority for Setagaya Ward as approximately 57 percent of its land area is publicly owned (excluding roads) and 49 percent is for residential use (Setagaya Ward 2016). The priority areas include those:
- That have experienced frequent flood damage in recent years (for more information, see **appendix, case 6**)
- Where public facilities are concentrated
- Where the installation of stormwater storage and infiltration facilities will be effective and is one of the goals of the community development plans
- Where installation of these facilities and promotion of watershed management is being considered

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23 Rainwater planters are planter boxes normally located in households, as street furniture, or as landscaping features within commercial development, with a capacity to retain rainwater by storing it within its soil, gravel, and plant roots. It can be made from new or recycled materials, and excess stormwater is normally designed to overflow through pipes at the bottom of the planter, which drains back into the system.

Step 3: Consensus Building and Responsibility Sharing

The Setagaya Ward Basic Policy for Heavy Rain sets out IUFRM roles and responsibilities for the ward and city government, and also encourages self-help and mutual help among residents, communities, the private sector, and civil society organizations. Therefore, engagement and consensus building with various stakeholders in the planning, implementation, and sustainability of these flood risk management measures are critical. Setagaya Ward works closely with existing community self-governance committees and business associations to conduct consultations, training sessions, requests for support, information sharing, and awareness raising throughout the flood risk management efforts. These efforts are implemented together and in line with Setagaya's community and citizens' engagement process for urban development, civil works, and DRM initiatives. (An example of a collaborative green infrastructure project, the Tamagawa Rise project, and the role and responsibility sharing between the public sector, private sector, and community is included in **Knowledge Note 3**.)

Consensus building and responsibility sharing with TMG and the national authority is very important for advancing Setagaya Ward's flood risk management efforts. This is done through clearly defining the relationship and roles of the ward, TMG, and the national government in the heavy rain policy and action plan. **Figure 11** illustrates how within the basic policy, stakeholders are responsible for specific flood management measures. This has led to close coordination during the development, operation, and maintenance of flood management measures implemented within the same location and/or watershed, such as coordinating the location of water storage or detention facilities (led by the ward) near the construction of new roads and underground discharge channels (led by the national government and/or TMG), and so on.

Figure 11: Setagaya Ward's Heavy Rain Measures and Responsible Stakeholders

Topic of Policy Measure	Focus	Tasks	Implementation Body: Nation-wide	Tokyo	Wards	Public Institution	Citizens	Business Operators
Promotion of rivers and sewerage improvements	River improvements	River improvement in the watersheds of Nogawa/Yazawa rivers		○	△			
	Sewerage improvements	Sewer improvement using a combined system		○	△			
		Sewer improvement using a separate system (stormwater)		○	△			
Enhancement of watershed management	Facilities managed by wards	Enhancement of watershed management in elementary and middle schools			○			
		Enhancement of watershed management in parks and open plazas			○			
		Enhancement of watershed management in offices and houses			○			
		Enhancement of watershed management in roads			○			
	Facilities managed by the national government and TMG	Enhancement of watershed management in roads and facilities managed by the national government and TMG	○	○	△			
		Enhancement of watershed management in facilities managed by public institutions			△	○		
	Private facilities	Enhancement of watershed management in large-scale private facilities			△		○	○
		Enhancement of watershed management in small-scale private facilities			△		○	○
		Enhancement of watershed management in private roads			△		○	○
		Enhancement of watershed management in existing houses			△		○	
	Promotion of rainwater use	Promotion of rainwater utilization facilities	△	△	△	△	○	○
		Promotion of rainwater tanks	△	△	△	△	○	○
	Promotion of green infrastructure		○	○	○	○	○	○
Promotion of measures for housing and urban development	Promotion of advance notice on flooding		△	△	○			
	Promotion of flood-resilient housing development				△		○	○
	Promotion of mechanisms for community and town development				△		○	○
Enhancement of evacuation measures	Promotion of advance notice on flooding				○			
	Promotion of flood-resilient housing development				○		○	○

○ Main body
△ Cooperation

Source: Authors' compilation based on information from Setagaya Ward (2018a).

Future Challenges and Next Steps

Monitoring and sharing the progress of implementation are critical actions. In order to continue and scale Setagaya's integrated approach to flood risk management, there is a need to continue to monitor the implementation of heavy rain measures to ensure close coordination and collaboration between various sectors and stakeholders. Key stakeholders are Setagaya Ward, local residents, businesses, the national government, and TMG. Furthermore, various sectoral departments—including sewerage, rivers, roads, urban development, environment, and DRM—all share roles and responsibilities in promoting heavy rain measures in Setagaya. To facilitate continued coordination and collaboration between these various groups, monitoring and sharing progress is key. Based on periodic progress reports, adjustments will need to be made to ensure effectiveness. Setagaya Ward has been using the "Plan, Do, See, and Action" cycle to monitor progress, and has been convening periodic committee meetings to review the progress of heavy rain measures, especially in high-priority areas.

Monitoring and evaluating performance are also important. In order to measure progress against targets, effective operation and maintenance of installed facilities, as well as the monitoring of their performance, are extremely important. Given that many green infrastructure investments are promoted in public facilities, Setagaya Ward aims to continue to closely monitor the performance of installed green infrastructure, such as rainwater infiltration and storage tanks, as well as ensure that effective monitoring takes place. Remaining challenges exist in the monitoring and maintenance of residential and private sector facilities. Some innovative initiatives for promoting the O&M and performance evaluation of green infrastructure are included in **Knowledge Note 4.**

Scaling flood management measures within the private sector and residential homes is essential to meet ambitious targets. Under the Setagaya Ward Heavy Rain Measures Action Plan, businesses and residents, especially new developments, are highly encouraged to manage stormwater through the installation of rainwater infiltration and storage measures. New developments having an area greater than 150 m^2 are required to submit a rain/stormwater management plan, but there is very little enforcement by the ward government. While most development in Setagaya and Tokyo so far complies with policy mechanisms to incentivize further uptake of stormwater management, raising awareness of the potential benefits of green infrastructure would help expand efforts to create it beyond the public sector. To this end, monitoring, evaluating, and quantifying the socioeconomic and environmental benefits of related investments (beyond flood risk management) are key.

5. Lessons Learned and Key Takeaways

This Knowledge Note explored Japan's process in planning and prioritizing related investments as part of an integrated approach to urban flood risk management. This included a description of the evolution of management of urban floods in Japan, in terms of policies and approaches, as well as a summary of the institutional arrangements and key roles and responsibilities of various stakeholders.

Related to the evolution of IUFRM in Japan, innovative efforts in the Tsurumi River Watershed in 1981 were instrumental in advancing the watershed-wide approach to flood risk management in Japan. The concept of an integrated approach to flood management was further advanced through the introduction of the SUFDML enacted in 2003 for eight designated rivers. In 2013, a 100 mm/hour Safety Plan was initiated by the MLIT to tackle the increasing impacts of concentrated heavy rain in urban areas. Responsibility for the safety plan is held by the local government and the public authorities for river and sewerage management. In addition, cities, in collaboration with the national government and research institutes, are increasingly exploring various ways to understand and integrate climate change risks within their flood management plans.

In terms of stakeholders, national and local governments, the private sector, citizens, and academia work together to set and achieve shared goals for mitigating the risks and damages of urban floods. Within the government, the departments managing rivers, drainage and sewerage, watersheds, urban planning and development, the environment, and DRM[24] collaborate to determine and share responsibility for actions to address identified flood risks.

The review of the planning and prioritization process focused on the role of local governments. In Japan, urban flood risk management plans and objectives are developed in line with the national Disaster Countermeasures Basic Law (DCBL). Based on this high-level goal, specific long- and short-term targets are developed to address the unique flood risks and geographic contexts of each city. Cities also prioritize certain regions or measures based on different regional flood risk contexts. During the process, cities use risk assessments (discussed in **Knowledge Note 1**), cost-benefit analyses, and engagement and consensus building with communities and stakeholders.

Cities are increasingly aware that flood risks cannot be managed effectively without considering structural and nonstructural measures. Key nonstructural flood risk management tools and approaches considered by cities in Japan include water, land use, and disaster risk management through urban planning, building codes, promoting awareness of flood risks, promoting relocation by providing risk information, and enhancing flood alert systems. Key urban development laws include Japan's City Planning Act, which regulates land use, urban facilities, and urban development projects in Japan, and the Building Standard Law and Urban Planning Law and Ordinance, according to which local governments can designate areas as vulnerable to disasters such as floods, tsunamis, and storm surges, and even prohibit construction of residential buildings in vulnerable areas and to set other development restrictions for disaster prevention. Throughout the process, cities actively engage the national government, local community, and private firms in order to not only build consensus on the proposed flood management investments, but also garner support in sharing responsibilities for the implementation of critical steps, such as design and construction, financing, and O&M. Private firms and communities are making greater investments in flood management to meet the increasing and diversifying risks of urban floods.

Based on the case reviews, this Knowledge Note identified a three-step process including goal setting, planning and prioritization, and consensus building. The lessons learned, outlined below, highlight aspects for other countries to consider. The **TMG**'s IUFRM approach shows how ambitious cityside flood risk management goals are set, together with sectoral targets and both structural and nonstructural measures, through a coordinated approach. **Shiga Prefecture** highlights progressive land use planning and building codes. **Setagaya Ward** demonstrates an active, bottom-up, community-led approach, with wide application of green infrastructure solutions providing multiple benefits simultaneously.

Finally, this Knowledge Note builds on the information about flood risk assessment and communication efforts presented in **Knowledge Note 1**; and prepares ground for information presented in **Knowledge Note 3**, which focuses on the design and implementation of specific solutions, as well as the operations and maintenance practices presented in **Knowledge Note 4**.

Step 1: Goal Setting

- **Regularly update goals based on evidence.** Goal setting is based on risk assessment simulations that take into account scientific evidence, including external forces such as historical rainfall in the targeted areas (see **Knowledge Note 1**) and known damages. Moreover, a city's integrated policy and improvement goals should be set based on comprehensive evaluations of their feasibility, efficiency, impact, and economy. Committees consisting of academic experts and local stakeholders are important in the course of decision making.
- **Align local and national goals.** Whenever available, the laws, guidelines, standards, and goals of the national government should be referenced to ensure alignment and consistency. At the same time, cities may foresee a need to develop their own city-level goals and plans for IUFRM, especially as flood risk management becomes more complex amid growing climate change risks. Cities in Japan have developed and utilized city-specific flood management plans, such as measures against heavy rains and watershed management, in order to understand the remaining risks and gaps that cannot be managed by large-scale structural measures led by the national government. They have sought to identify opportunities to develop flood management measures through engagement of various stakeholders (public, private, academia, and community), sectors (river, sewerage, watershed, urban planning and development, environment, and DRM), and approaches (structural, nonstructural, and green). In this way, cities in Japan are putting forth a framework for how to save the lives of people in the face of any type of expected or unprecedented flood event, and reducing damages to assets and economic losses.
- **Pair long-term goals with realistic milestones.** Citywide flood management goals, linked with cities' overall urban development priorities, are set based on the results of flood risk assessments, and consider the following factors: (i) characteristics of areas and floods; (ii) the efficiency of past flood management efforts; (iii) capacity and impact of each sector, including rivers, sewerage systems, and watersheds; (iv) clarification and segmentation of goals and indicators; (v) phased IUFRM development planning; (vi) consistency with the relevant river basin plan; and (vii) impact on society and the economy. The experience of Tokyo and many other cities in Japan demonstrates the importance of ensuring that overall long-term flood risk management goals be kept ambitious, in order to effectively plan for expected risks as well as worst-case scenarios (i.e., probable maximum precipitation, etc.). At the same time, realistic milestones set for a specific time frame (for the medium to short term) and sector can be helpful to monitor progress and evaluate the effectiveness of the plan.
- **Consider the effects of climate change.** Considering the uncertainty of climate change and unknown risks, stakeholders must recognize and prepare for external forces that exceed the capacity of planned measures, especially of structural measures. Additionally, it is important to simulate incidents in which facilities cannot prevent inundation, and share disaster risk information with all stakeholders to cope with increasingly intense floods. These simulations should consider a range of external forces based on flood design scales. The information gathered from risk assessments should be leveraged by all stakeholders in implementing all possible measures for flood risk reduction. Therefore, Japan has been communicating the risk of unprecedented events to citizens. Based on this understanding, communities should prepare for floods and publicize possible inundation areas according to the highest design scale. This management method is based on the Flood Prevention Act, which was partly revised in 2015.

Step 2: Integrated Planning and Prioritization

- **Share responsibilities to advance common goals.** Once a citywide flood risk management goal is set, sectoral targets are determined based on various factors including: (i) the city's strategy and vision; (ii) the nature of mandates and role sharing between each sector (river or sewerage bureau) for current flood risks; (iii) assignment, budget allocation, and inputs such as technical and social feasibility analysis of management goals; (iv) advice from academic experts sitting on committees; (v) assignment of planning and management goals; and (vi) prioritization of implementation steps. While sectoral departments commit to separate flood management targets, close coordination and collaboration enable the effective implementation of IUFRM. For example, given the close relationship between sewerage management and river improvement projects (as rainfall will drain into either river or sewerage systems), if the progress of a river improvement project is slow, then it impacts the stormwater management capacity of the adjacent sewerage systems. Therefore, the timing of construction should be closely coordinated.
- **Integrate structural and nonstructural measures.** Understanding the strengths and weaknesses of different IUFRM measures is important. Structural measures significantly reduce flood risk but require large budgets and ongoing maintenance. On the other hand, nonstructural interventions, such as the creation of hazard

maps and evacuation training, are comparatively low cost and can be started immediately. Thus, nonstructural measures complement structural measures, and are important in reducing flood risks and damages until appropriate structural measures are in place. Also, nonstructural measures such as land use planning, zoning, and DRM can help mitigate damages caused by floods that exceed design levels. Green or nature-based structural measures are normally multipurpose and can result in diverse benefits besides flood risk management, such as urban and community revitalization, environmental sustainability, and livability enhancement. The process of the site-specific selection and design of flood management measures will be further discussed in **Knowledge Note 3.**

- **Prioritize measures based on local contexts.** Prioritization of IUFRM within the sector and at the project level should be based on weighing the pros and cons as well as costs and benefits of various measures vis-à-vis local hazards and socioeconomic and cultural factors. Cities set different targets for flood risk management within their municipal boundaries based on different geographic and hazard risk characteristics, as seen in the case of TMG and Shiga Prefecture. Additionally, critical infrastructure, such as schools, hospitals, and transportation networks (e.g., the underground metro) may also require different approaches to prioritizing progressive and function-specific IUFRM measures and approaches. CBAs are often undertaken at the project level to compare various IUFRM approaches and tools appropriate for the site. As IUFRM approaches expand and diversify, there is a need to further develop CBA methods to effectively integrate the various nonquantifiable benefits that may go beyond flood risk management, particularly for nonstructural and green (nature-based) solutions.

Step 3: Consensus Building and Responsibility Sharing

- **City governments have a key role to play in brokering partnerships for IUFRM.** IUFRM is an integrated approach that is driven and implemented by a wide range of sectors and stakeholders, as described above. Therefore, the city government has a significant role to play in garnering consensus among a diverse and expanding set of stakeholders. There are several tools and approaches that can be used in the consensus-building process, including joint conferences involving academia, related governmental divisions, and residents; joint risk assessments and flooding simulations of river floods and surface water floods (as seen in the case of Tokyo's river and sewerage bureaus); public hearings; consultation with the private sector; incentive systems such as subsidy schemes and legal regulations; and periodic personnel exchanges within governmental organizations.
- **Roles and opportunities for the private sector and community members are growing.** Additionally, there is a significant need—and opportunity—for the private sector and community to take the lead in flood risk management. The public sector's capacity alone is not enough to mitigate expected and unprecedented flood risks that may put the lives and livelihoods of citizens in danger. Therefore, various financial incentives, technical assistance, human resource development, awareness raising, and information sharing with diverse stakeholders will be much needed to further expand various innovative IUFRM efforts in cities.

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Knowledge Note 3: Designing and Implementing Urban Flood Risk Management Investments

Cover Image: A stormwater intake chamber built alongside the Myoshoji River in Tokyo (at the border of Nakano and Shinjuku wards). During storm events, the river water overflows into detention ponds as well as large spaces upheld by pilotis under the Tetsugakudo Park Collective Housing complex. This avoids damaging inundation of the surrounding residential area.

(Photo Credit: Kenya Endo)

1. Summary

This Knowledge Note summarizes the experiences of and lessons learned by Japanese cities that have designed and implemented various types of urban flood risk management investments. Building on the broad principles outlined in **Knowledge Note 2** of the same series, and on a review of 20 cases (detailed in an **appendix**) across Japan, this note focuses on five categories of investment criteria:

1) Flood management and investment objectives
2) Technical considerations
3) Urban development and finance
4) Governance and stakeholders
5) Multipurpose infrastructure

The specificities of each context inform and determine the enabling environment for investment, and also the feasibility and relevance of various mechanisms to manage flood risks.

Cities design and implement site-specific schemes to manage urban flood risks based on the type and extent of the risks assessed (discussed in **Knowledge Note 1**), **as well as the goals and sectoral targets of their flood management plans** (discussed in **Knowledge Note 2**). To address various types of urban flood risk (river, surface water, and storm surge floods), Japanese cities combine structural and nonstructural measures. Of structural measures, both "gray" (heavy infrastructure)" and "green" (nature-based, multipurpose interventions) are being increasingly explored in Japan. Through trial and error, many cities are identifying the challenges and merits of combining structural and nonstructural as well as gray and green solutions. Such combinations often enhance the overall effectiveness of urban investments in flood management, in some cases at less cost to the public sector and other stakeholders involved.

Investing in efforts to reduce and manage urban flood risks requires cities to carefully select those measures that promise to be most effective and efficient in a given context. Cities must be able to understand and weigh the strengths and weaknesses of various options, assess the range of flood management measures available, and consider the enablers needed for implementation. This can be a daunting task, given obvious limits to the information, time, and resources needed to thoroughly understand and explore the array of flood risk management options.

This note highlights the following key lessons learned from Japan's experience in designing and implementing effective flood management investments in urban settings:

- **Consider multiple factors and criteria.** Design and implementation involve much more than technical solutions. Cities across Japan have taken a multifaceted approach that considers multiple interrelated factors including the type of flood risk, spatial and financial considerations, and implementation arrangements.
- **Design multipurpose interventions that offer multiple benefits.** Cities face an array of social, economic, and environmental challenges at once and must balance many needs and priorities beyond those related to disaster and climate risks. Finding opportunities for synergy is the most practical way to maximize the space and resources available to a city and its residents. Examples from Japan showcase various ways in which collaboration and partnerships can be effectively brokered to support multiple purposes and benefits. Cities such as Yokohama and Tokyo, for example, have achieved synergies across the goals of urban flood risk management, urban development, and environmental conservation as they work to create safe and livable urban spaces.
- **Engage the private sector and local communities.** As the number and diversity of urban flood risks increase, cities in Japan are aware of the need to engage diverse stakeholders and coordinate roles and responsibilities to most efficiently finance, implement, and expand measures to manage the risks. Many cities have explored ways to partner with and incentivize initiatives led by private developers and communities. For example, in the process of upgrading the Shibaura Wastewater Treatment Facility to enhance its stormwater and wastewater

management capacity, the Tokyo Metropolitan Government (TMG[1]) Bureau of Sewerage collaborated with the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and NTT Urban Development (a private sector developer). The tools and mechanisms trialed included regulatory mechanisms, the establishment of standards and guidelines, subsidy programs, flexible urban development standards, information sharing, and awareness raising campaigns. For example, under the administrative guidance requirements ("gyosei shido" guidelines), local governments in Japan require developers to construct flood retarding basins to compensate for the expected increase volume of rainwater runoff due to development.

- **Utilize new technologies and systems.** Based on lessons from various disaster events, cities in Japan, together with research institutes and firms, have worked to advance and apply various new technologies in construction methods, materials, and management systems to enhance the effectiveness of flood management measures. For example, Hachioji Minamino City worked with the Hachioji New Town Water Circulation Conservation Systems Committee (led by academics from the University of Fukushima) to evaluate the city's hydrological cycle conservation system using the SHER[2] model (Japan Riverfront Research Center 2007). Similarly, Setagaya Ward has collaborated with various universities and engaged communities to design, implement, and monitor green infrastructure solutions. These iterative and incremental processes of monitoring and improvement have ensured the continued relevance and effectiveness of both structural and nonstructural approaches to urban flood risk.

2. Designing Investments for Various Types of Flood Risk

2.1 Factors and Criteria Considered by Cities

In designing a site-specific effort to manage urban flood risk, various factors need to be considered to ensure successful implementation. In particular, the project's benefits (outcomes) and requirements (to create an enabling environment) must be considered in relation to planners' objectives and available resources.

Flood Management and Investment Objectives

Cities may deliberate on one or a combination of approaches to managing the various types of flood risk. Selecting a measure that is suited to a site's flood risk profile (including proximity to water bodies, characteristics of the built environment, etc.) and planning and development objectives (including risk management targets laid out in city and national plans, etc.) is critical.

Investments in the management of urban **river floods** primarily aim to: (i) avoid water overflow from a river into an urban area by increasing the river's conveyance capacity (via widening or dredging) or constructing a structure (e.g., river embankment) that serves as a barrier; and (ii) temporarily store river overflow in sites away from urban centers, whether underground (in cisterns, channels, etc.) or above ground (in reservoirs, detention parks, and ponds).

Investments in managing urban **surface floods** primarily aim to manage the volume of water that enters urban drainage/sewer systems through: (i) temporarily storing stormwater in management facilities that may be underground (such as cisterns, channels, drainage pipes, culverts, etc.) or above ground (such as stormwater detention ponds, parks, and gardens); (ii) adding storage capacity to existing facilities that may be used for detention (e.g., sewerage system); (iii) harvesting rainwater in tanks within public, commercial, and community

1 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.[a]).

2 Similar Hydrologic Element Response.

buildings; and (iv) increasing the infiltration capacity of urban surfaces through the use of green spaces, pervious pavers, infiltration trenches, and so on to reduce stormwater runoff. It must be noted that even small-scale interventions can have a large collective effect when installed throughout a city. These investments are combined with various other measures to avoid water inundating the urban areas, such as river and coastal management measures (seawalls and embankments) as well as pumping systems.

Investments in urban **storm surge flood** management generally aim to: (i) prevent seawater surge into urban areas by constructing barriers (e.g., seawalls or flood gates), and/or (ii) raise the ground or platform level of affected structures to avoid damages due to seawater inundation. In Japan, most storm surge flood management projects are also designed to jointly manage tsunami risks, given the vulnerability of the country's entire coastline to seismic activity.

In general, the flood management capacity depends on the size of the infrastructure, which is often limited by the availability of financial resources and land. Flood management schemes applicable to **all flood types** generally aim to: (i) avoid urban development in flood-prone areas, through risk-informed land use planning and zoning; (ii) ensure that construction in flood-prone areas can withstand certain levels of flood risks, through appropriate building codes; and (iii) equip the affected population with information needed to protect their lives and livelihoods in case of flood disasters, through early warning systems, accessible evacuation centers, access to risk assessments/risk information, education, drills, efforts to raise awareness, and so on. Land use plans and zoning can go far in mitigating flood risk by deterring development in high-risk areas, thereby reducing vulnerability and asset exposure, but these interventions do not directly minimize the flood hazard itself. Similarly, building codes, early warning systems, and communication efforts can be effective in reducing losses and damages to lives and assets from flood events, but they do not directly protect developed areas from the occurrence of floods.

Urban Development and Finance: Considering Space and Cost

Given competing development pressures, the spatial and financial requirements of interventions are critical to consider. **Flood management investments with a high cost and large surface footprint,** such as reservoirs, detention parks, river embankments, sea walls, and ground raising are feasible options when: (i) high-value assets are located near or within the affected watershed, and a significant socioeconomic impact is expected without a large-scale investment; and (ii) an entity or group of entities can finance the high cost and coordinate complex consensus building, land acquisition, relocation, and construction processes. These tend to be in or near **high-density urban centers located near large rivers and coastlines**—that is, the conditions of most major cities in Japan.

Flood management investments with very high costs and a medium-sized to small surface footprint, such as underground river overflow management and stormwater facilities (e.g., cisterns, channels, drainage pipes, culverts), and the capacity expansion of sewerage systems are feasible options when: (i) very high-value assets are faced with the risk of a significant socioeconomic impact from floods; and (ii) an entity, normally from the public sector, has the capacity, authority, and access needed to develop an underground facility. These tend to be in **very high-density urban centers where space above ground is limited**.

Flood management investments with medium to low costs and medium-sized to small space requirements, such as storage in ponds and gardens, harvesting and reuse of rainwater, surface modification to enhance infiltration and reduce runoff, and the establishment of evacuation centers are feasible options when: (i) public and private spaces can be made available, and (ii) the level of awareness and participation of various public sector departments, the private sector, and community members is high. These tend to be located in **medium- to low-density urban areas where space above ground is available**.

Technical Considerations: Positive and Negative Impacts

In addition to traditional technical surveys and feasibility-level studies, when designing a flood risk management scheme, it is important to keep in mind several technical factors, outlined as follows:

- **Flood management capacity.** Cities invest in initiatives to address existing flood risk challenges and meet citywide flood management targets. Therefore, the type of proposed investment and the extent to which it reduces flood risks (that is, its capacity to manage floods) are key considerations. For example, the high-standard embankment in Komatsugawa can accommodate up to a 1-in-200-year river flood (appendix, case 1), while the Arakawa River No. 1 detention facility can store up to 39 m^3 of river overflow or up to 850 m^3/sec water volume and aims to accommodate up to a 1-in 200-year storm event (appendix, case 4).

- **Cost-effectiveness.** Faced with aging and shrinking populations, cities are likely to find it increasingly difficult to secure public funds and resources for flood risk management, even as the risks of disaster increase. Thus, cities are looking for ways to do more with less. During early stages of the design process, it is important to examine the life-cycle costs of an investment, and to explore new partnerships, technologies, and construction and operation and maintenance (O&M) approaches that may be integrated into an initiative's design to save costs and increase benefits.
- **Environmental impacts.** Positive and negative environmental impacts related to water quality, access, ecosystem services, water circulation, biodiversity, and so on are to be evaluated. After analysis of the data, solutions for how to minimize negative impacts and maximize benefits may be proposed and integrated into the final design of an intervention.
- **Social impacts.** Positive and negative social impacts are important to consider in the design and implementation of flood management investments. For example, requirements for land and for residents' temporary and/or permanent relocation may have negative impacts on local communities. On the other hand, integration of flood management investments within public and/or green spaces may create positive social impacts, catalyzing community-led initiatives and fostering the cohesion of local communities.
- **Requirements for operation and maintenance.** Effective O&M practices are critical to enhance and/or prolong the capacity and effectiveness of a given flood management facility or solution. The frequency and technical and financial requirements for O&M are key factors that need to be considered during the design phase. Knowledge Note 4 focuses on these issues.
- **Innovation and technology.** Various technological innovations are drastically changing the way city systems and inhabitants operate and interact. Today, more than ever before, planners are aware of the need to explore opportunities to integrate and adapt to these fast-changing technological contexts. Innovations in construction processes and materials, as well as technological tools that can be used to enhance stakeholder engagement, consensus building, and risk awareness and communication, are all key design considerations for cities to ensure flood management investments are relevant today and in the future.

Governance and Stakeholders: Which Stakeholders Are Leading the Investments?

As discussed in **Knowledge Note 2**, it is critical to consider and categorize all project stakeholders before designing an intervention. The governance framework, too, is key to an intervention's success. Key factors are summarized as follows:

- **Policy and governance framework.** National and municipal policies and legal frameworks—such as those related to stormwater management, river management, urban development, environmental standards, disaster risk management, etc.—provide key directions and technical guidelines for the types of flood management measures that may be implemented and how they are designed in Japanese cities. At the project level, especially when responsibilities are being shared among different stakeholders, the need to establish new operational procedures and governance mechanisms becomes an important design consideration. For example, in Japan the use of collected water in a rainwater harvesting system is limited to those functions authorized by the Act to Advance the Utilization of Rainwater (MLIT 2015); these include its use in toilets and for watering plants, cleaning purposes, environmental purposes, and fire and emergency management.
- **Stakeholders.** As detailed in **Knowledge Note 2** (**table 5**), large-scale, structural interventions to manage river and storm surge flood risk are led in Japan by the national government, under the leadership of MLIT, while smaller-scale, structural and nonstructural river, surface water flood, and multihazard investments are led by municipal governments, the private sector, and communities. Area-wide structural investments that require consensus building with citizens, land readjustments, and the relocation of assets or residents (such as river embankments, seawalls, ground-raising investments, some reservoirs, and detention parks) often combine flood management initiatives with urban redevelopment or environmental conservation efforts. Therefore, they are implemented through a coordinated effort between the national government (MLIT), municipal government (e.g., river, urban development, and environment departments), and private sector (e.g., housing development authorities). Partnering with community and private sector groups to design, build, finance, operate, and maintain flood risk management investments may require extensive coordination, but can significantly reduce the lifetime costs and maximize the benefits of an intervention.

- **Site-specific structural investments utilizing public space** above and below ground (such as underground river overflow and stormwater management facilities, reservoirs, detention parks, sewerage treatment plan enhancements, rainwater harvesting systems, and the enhancement of infiltration surfaces) are normally led **by municipal governments**. In recent years, **innovative ways of incentivizing private and community participation**, especially in the O&M of these facilities through private finance initiatives, are growing (showcased in **Knowledge Note 4**).

- **Structural investments utilizing privately owned land** (e.g., buildings, residences) above and below ground (such as detention parks, ponds, gardens, rainwater harvesting systems, and the enhancement of infiltration surfaces) are normally led by **private and community stakeholders**, often with education, awareness raising, technical support, and financial **incentives provided by municipal governments.** Through subsidy programs, the provision of technical guidelines, and the implementation of educational campaigns, public, private, and community stakeholders coordinate and collaborate to achieve the scale required for these small interventions to contribute to citywide flood management goals. Public-private partnerships, private finance initiatives, and other forms of private sector participation have been trialed to improve the efficiency of investments as well as reduce O&M costs, and share the cost burden.[3]

- **City- or communitywide nonstructural investments** (such as land use plans, zoning and building codes, early warning systems and evacuation centers, risk assessments, drills, and efforts to raise awareness) are normally led by **municipal governments' urban planning and development and disaster risk management departments.** Cities often collaborate with community groups, technical experts, schools, and hospitals to design and implement these initiatives. Examples from Ozu City, Ehime Prefecture, Sanjo City, and Niigata Prefecture are highlighted in **Knowledge Note 1**.

Multipurpose Infrastructure

Faced with competing development pressures and pressing priorities, cities are tasked to find creative ways to derive multiple types of benefits serving various stakeholders and purposes within a single intervention. There is a significant opportunity to harness additional benefits from proposed flood management investments (such as integrating green design elements, and engaging the public and private sectors to build, operate, and manage facilities, etc.) or to ensure that other urban initiatives (such as environmental conservation and urban development/renewal projects, public or private infrastructure or facility upgrades, etc.) also support flood management targets. Amid new research and technological advancements, structural approaches can involve both gray (hard-engineered) and green (nature-based) infrastructure.

Cities interested in advancing environmental sustainability and livability[4] are also promoters of green infrastructure, often through collaboration with private developers and financial institutions interested in fulfilling a commitment to advance environmental, social, and governance investments. Major cities investing in green infrastructure solutions include Setagaya Ward in Tokyo, as well as Yokohama City. The public sector in general is growingly increasingly more interested in green approaches to complement gray solutions, given the growing challenges of an aging infrastructure, a shrinking population, and limited human and financial resources (Development Bank of Japan 2019). For example, traditional concrete river embankments and seawalls can be combined with trees, or the height of an embankment can be reduced if complemented by other solutions such as natural wave breakers. Similarly, the size and design of storm drains, pumps, and outfalls can be redesigned with a reduced footprint when combined with nature-based infiltration systems and/or water detention facilities, such as rain gardens, etc.[5] In Japan, efforts to utilize green infrastructure solutions for flood risk management are still at their initial stages, although nature-based solutions have deep cultural and historical roots. Experience to date shows that: (i) reservoirs, detention parks, and ponds for river floods are widely adopted (examples include Saitama Prefecture and Setagaya Ward); and (ii) the application of nature-based solutions for stormwater detention ponds, parks and gardens, rainwater harvesting systems, and enhancement of infiltration surfaces is growing in Japanese cities.

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3 For lessons learned on resilient infrastructure public-private partnerships, please see Shibuya and Sasamori (2017).
4 The Economist Intelligence Unit (EIU), for example, assesses the "livability" of cities across five dimensions: stability, health care, culture and the environment, education, and infrastructure (Ellis and Roberts 2016).
5 See Browder et al. (2019) for a discussion of how nature-based solutions can produce lower-cost and more resilient services.

Box 1: Spotlight on Structural (Gray and Green Infrastructural Measures) and Nonstructural Measures for Urban Flood Risk Management Investments

As described in **Knowledge Note 2**, amid increasing and diversifying risks of floods, cities are increasingly aware of the importance of integrating structural and nonstructural measures, as well as gray (hard-engineered) and green (nature-based) solutions during the design and implementation of flood risk management investments. Key strengths and weaknesses of three types of such investments are summarized below:

- **Gray infrastructure measures. Key strengths** include large flood management capacity and relatively straightforward coordination in operation and maintenance (if governance mechanisms are clarified in advance). **Key challenges** include high construction costs and potentially long construction times, as well as high operation and maintenance costs over time, which are borne mainly by the public sector. Additionally, gray infrastructure is often designed solely to manage a specific type or level of flood risk. As a result, some large-scale flood management facilities, such as underground cisterns and channels, may be used only once a year or whenever large-scale flood events strike. Built to a set design level, traditional flood mitigation facilities are unable to manage flood risks above such levels.

- **Green infrastructure measures. Key strengths** include the functions and benefits that these generate beyond flood management, with green spaces and amenities often increasing the economic, social, and environmental value of an area. This can attract and engage private and community stakeholders to play a role in the design, financing, construction, operation, and maintenance of these measures, and thus share roles and responsibilities in managing the investment. Green infrastructure may also offer more flexibility than gray infrastructure, given its higher adaptability to changing environmental conditions. Furthermore, multipurpose investments can be utilized more frequently by various stakeholders and are often valued as a public amenity that may increase the property value of surrounding land. **Key challenges** include the high level of time and effort needed for stakeholder coordination, lower flood management capacity compared with gray infrastructure measures, and the difficulty of assessing, as well as monitoring and evaluating, the actual effectiveness of these measures in managing floods and realizing other intended benefits.

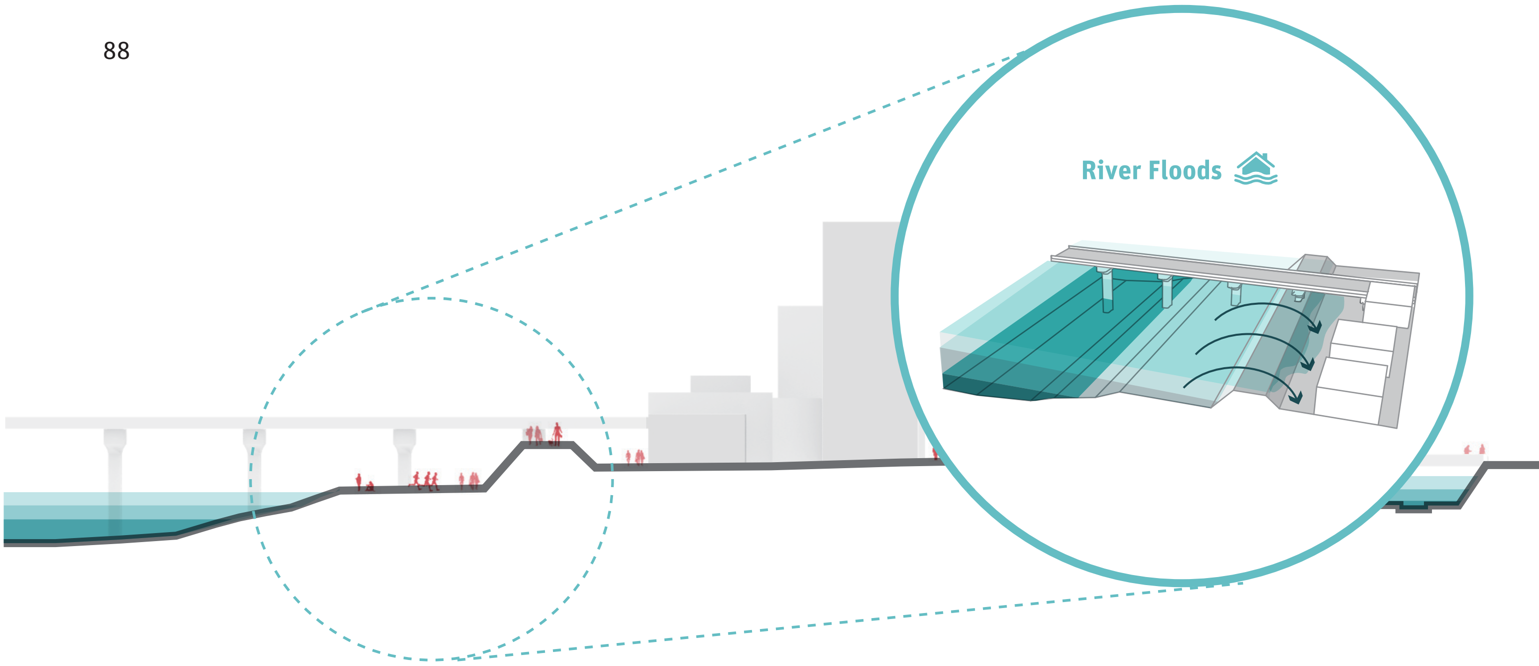
- **Nonstructural measures. Key strengths** include the ability to reach a large population at a relatively low cost (i.e., through education campaigns, dissemination of hazard maps, training and drills to raise awareness, establishment of early flood warning and evacuation systems, etc.). These measures aim to equip people with the information and knowledge they need to save their own lives and prepare for disaster so as to minimize damage and loss to their assets and livelihoods, including in the case of unprecedented flood and inundation levels. **Key challenges** include limitations in the degree to which these measures can avoid or mitigate the impact of floods. Effective flood evacuation measures can save lives but their ability to avoid and reduce damage to assets and livelihoods may be limited compared with structural measures.

Integrating Green and Gray: Creating Next Generation Infrastructure (Browder et al. 2019) is a joint report from the World Bank and the World Resources Institute (WRI) that aims to advance the integration of green and gray infrastructure solutions on the ground, and provides further analysis on the enabling environments and lessons learned in implementing an integrated approach to flood risk management.

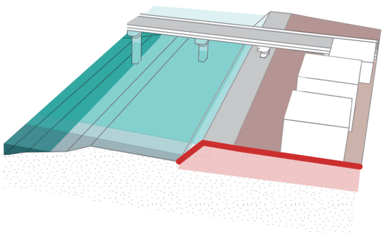
3. Implementing Urban Flood Risk Management Investments in Japan

Considering the above factors and criteria, Japanese cities are exploring a range of approaches and options to determine the scope, elements, and design of site-specific flood management measures, and initiate investments that are most suitable to local contexts. The planning and prioritization process is explained in **Knowledge Note 2**. An overview of the types of flood risk management investments common in Japan, along with specific examples from the case studies detailed in the **appendix**, is provided in **figure 1**, which spans the next several pages. While river dredging and widening, as well as the construction of dams and reservoirs upstream of vulnerable watersheds, are important elements of integrated flood management in Japan, they are not included in this Knowledge Note, which focuses on city-level interventions.[6]

6 A comprehensive review of structural and nonstructural measures used for integrated flood risk management globally can be found in Jha, Bloch, and Lamond (2012).



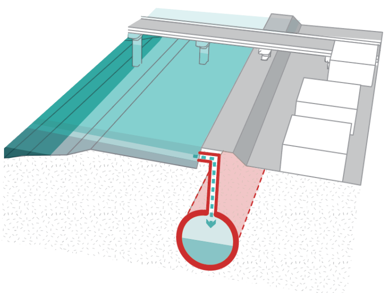
River embankments



Case 1
Reducing River Flood Risk and Promoting Urban Redevelopment:
Komatsugawa High-Standard Embankment

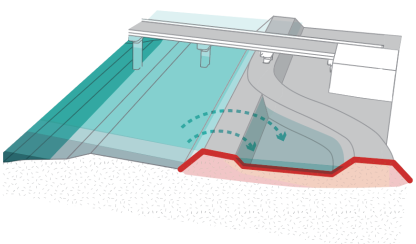
Case 2
Reducing River and Surface Water Flood Risk by Integrating Nature-Based Solutions within an Urban Redevelopment Project:
Futakotamagawa Rise and Futakotamagawa Park

Underground river overflow management facilities **(cisterns, channels, etc.)**



Case 3
Reducing River Flood Risk by Installing Underground Overflow Management Facilities:
Underground Detention Cistern beneath Loop Road No. 7

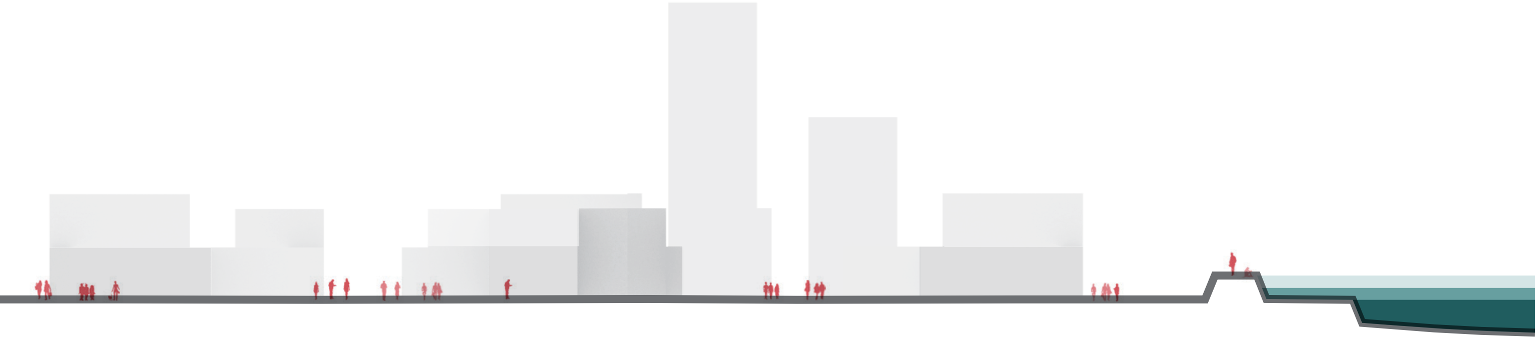
Reservoirs, detention parks, and ponds

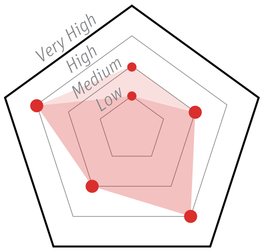


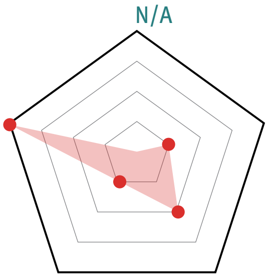
Case 4
Reducing River Flood Risk by Installing a Multipurpose Detention Park and Reservoir:
Arakawa River No. 1 Detention Facility

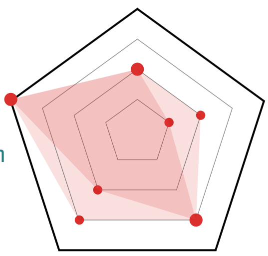
Case 5
Reducing River and Surface Water Flood Risk through Sharing the Costs of O&M:
Tetsugakudo Park Collective Housing and Myoshoji River No. 1 Detention Pond

Figure 1, continued from previous page









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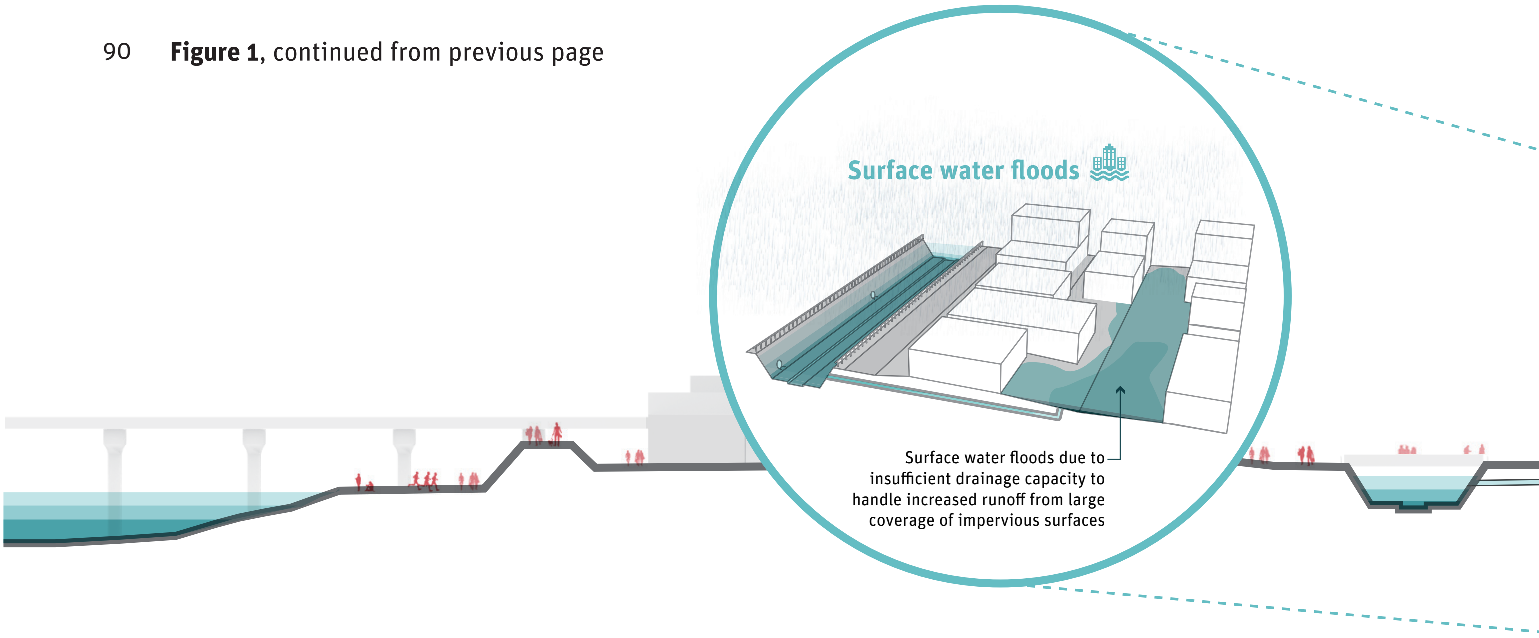
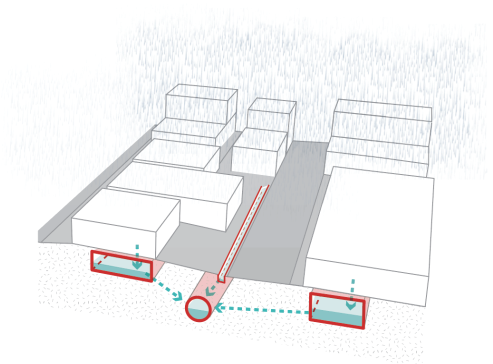


Underground stormwater management facilities
(cisterns, channels, drainage pipes, culverts, etc.)

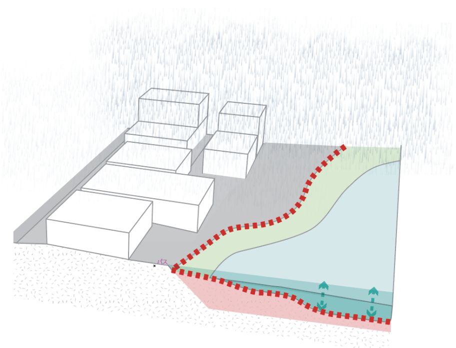


Case 6
Reducing Surface Water Flood Risk with an Underground Stormwater Management Facility:
Drainage Pipe System Improvement, Tokyo

Case 7
Reducing Surface Water Flood Risk by Installing an Underground Stormwater Management Facility with Other Public Facilities:
Minamisuna Detention Pond (7a) and Hibiya Crossing Detention Pond (7b)

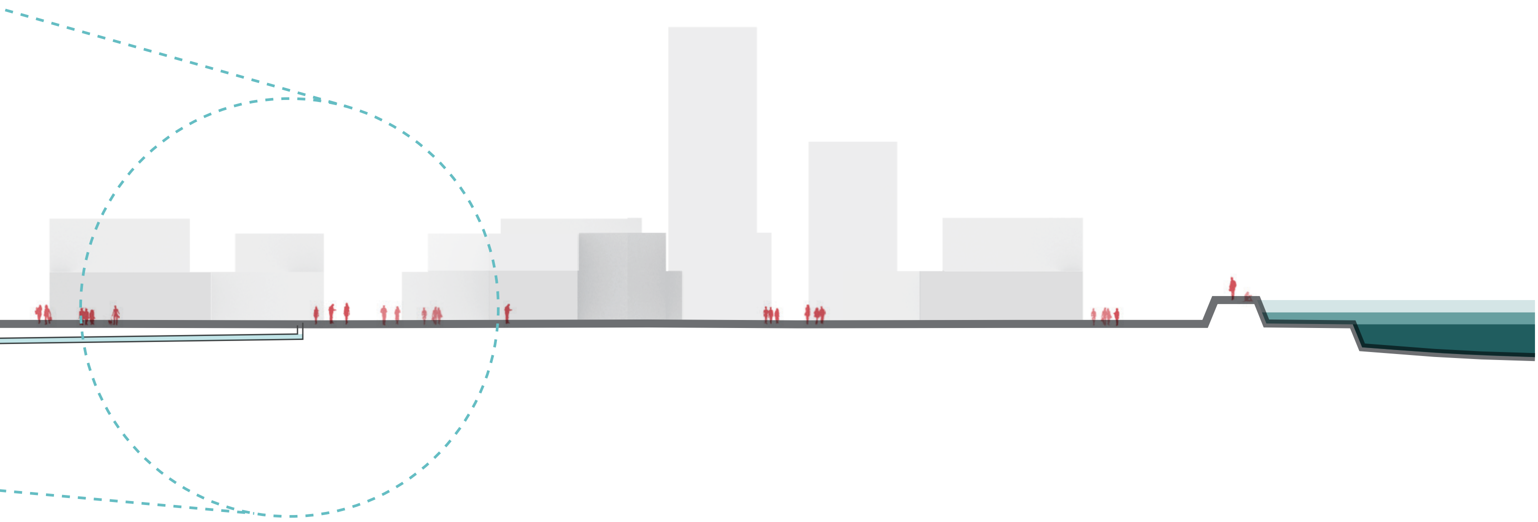
Case 8
Reducing Surface Water Flood Risk by Installing an Underground Stormwater Management Facility:
Yokohama Station Tower and Excite Yokohama 22 District

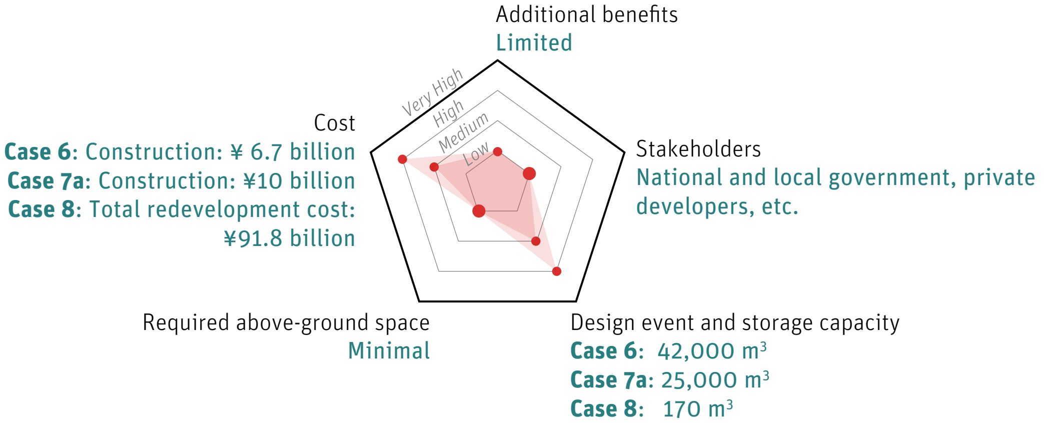
Stormwater detention ponds, parks, and gardens



Case 9
Reducing Surface Water and River Flood Risk by Integrating a Reservoir into Large-Scale Urban Development:
Koshigaya Lake Town

Case 10
Reducing Surface Water and River Flood Risk by Implementing Reservoirs, Detention Ponds, and Parks:
Saitama Prefecture




Additional benefits
Limited
Very High
High
Medium
Low
Stakeholders
National and local government, private developers, etc.
Cost
Case 6: Construction: ¥ 6.7 billion
Case 7a: Construction: ¥10 billion
Case 8: Total redevelopment cost: ¥91.8 billion
Required above-ground space
Minimal
Design event and storage capacity
Case 6: 42,000 m³
Case 7a: 25,000 m³
Case 8: 170 m³

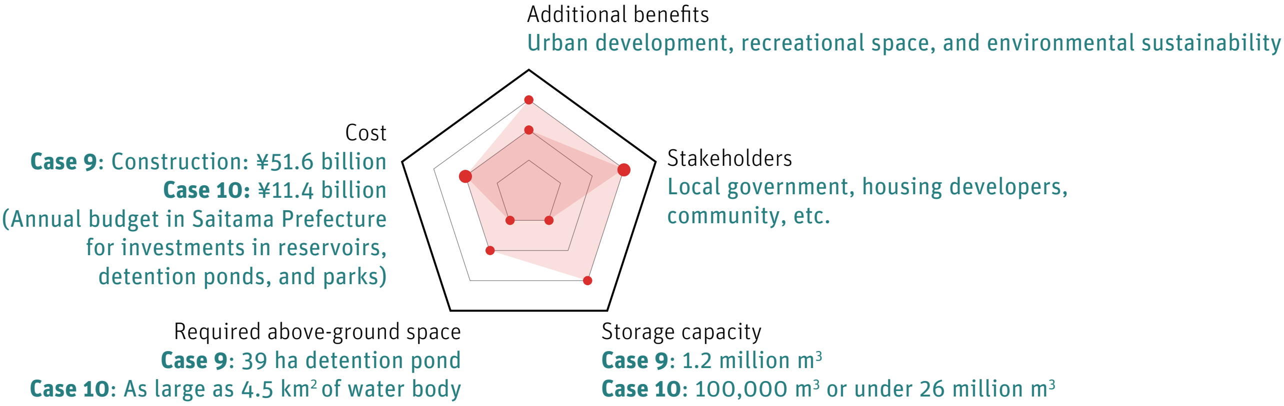
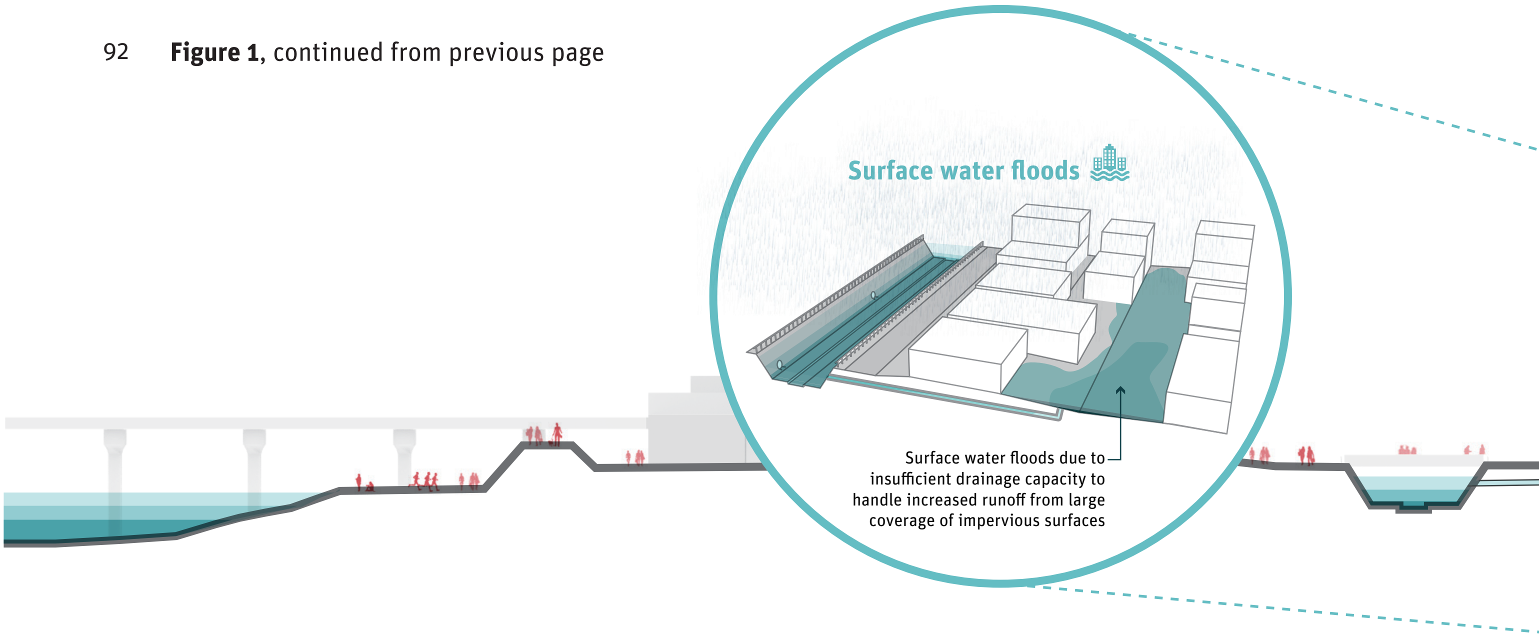
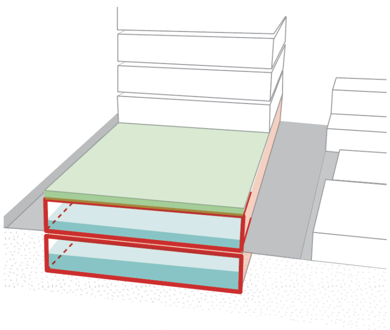

Additional benefits
Urban development, recreational space, and environmental sustainability
Stakeholders
Local government, housing developers, community, etc.
Cost
Case 9: Construction: ¥51.6 billion
Case 10: ¥11.4 billion
(Annual budget in Saitama Prefecture for investments in reservoirs, detention ponds, and parks)
Required above-ground space
Case 9: 39 ha detention pond
Case 10: As large as 4.5 km² of water body
Storage capacity
Case 9: 1.2 million m³
Case 10: 100,000 m³ or under 26 million m³

 Figure 1, continued from previous page

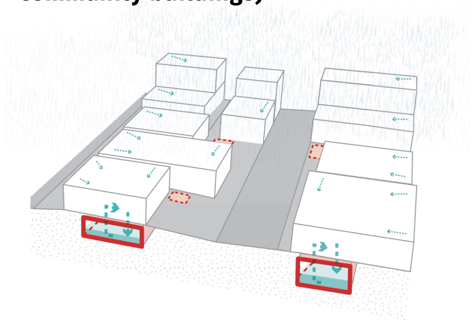


Sewerage treatment facility improvement



Case 11
Reducing Surface Water Flood Risk by Enhancing a Sewerage Detention Facility in Collaboration with the Private Sector:
Shibaura Wastewater Treatment Facility

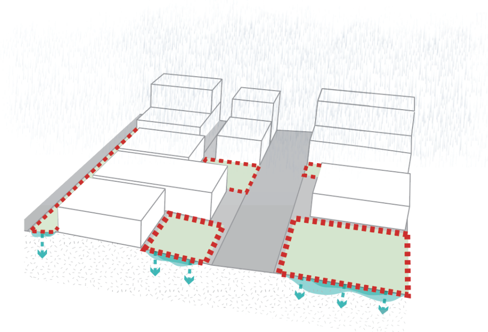
Rainwater harvesting systems **(collection systems and storage tanks installed in public, commercial, community buildings)**



Case 12
Reducing Surface Water Flood Risk through Community-Based Rainwater Harvesting Systems:
Sumida Ward, Tokyo

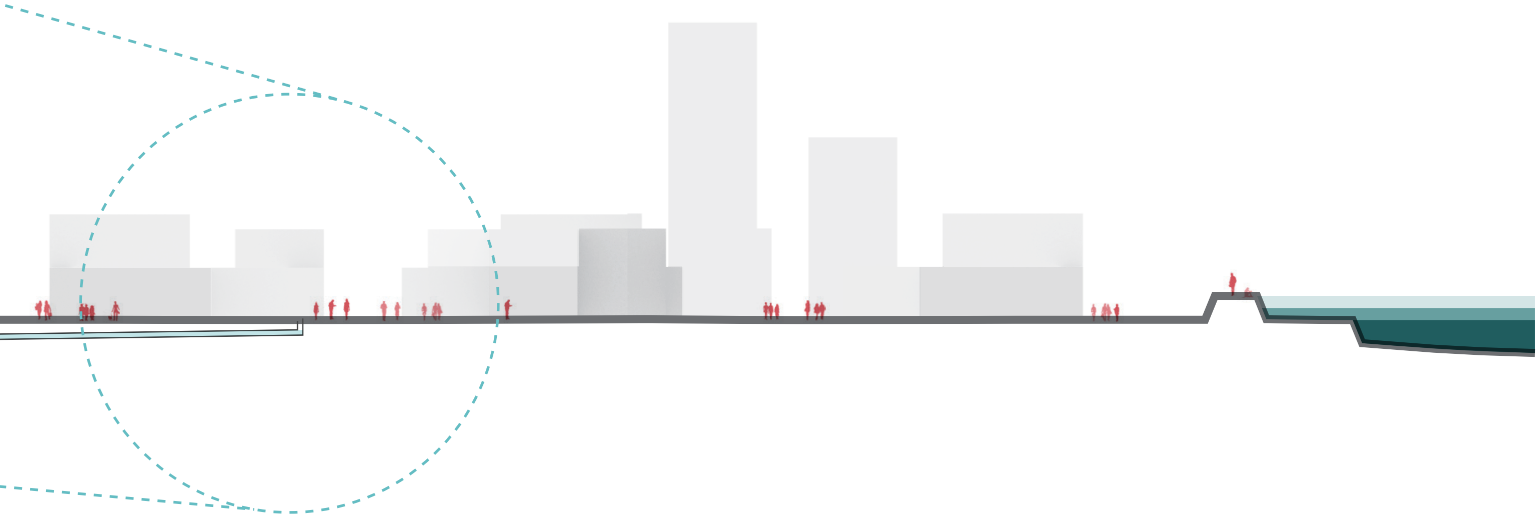
Case 13
Reducing Surface Water Flood Risk by Implementing a Rainwater Harvesting Tank in a Private Urban Development:
Tokyo Skytree Town

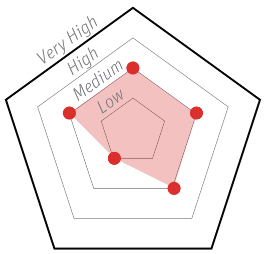
Increasing surface permeability **(green space, pervious pavers and infiltration trenches, etc.)**

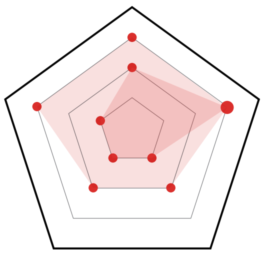


Case 14
Reducing Surface Water Flood Risk by Enhancing Pervious Surfaces and Detention Ponds in a New Town Development:
Hachioji Minamino City

Case 15
Reducing Surface Water Flood Risk by Enhancing Pervious Surfaces:
Grand Mall Park in Yokohama City




Additional benefits
Urban redevelopment, environmental sustainability, and recreational space
Very High
High
Medium
Low
Cost
Construction: ¥20 billion
Stakeholders
National and local government,
housing developers, etc.
Required above-ground space
Minimal
Storage capacity
76,000 m³ storage capacity


Additional benefits
Urban redevelopment, DRM, and water consumption saving
Cost
Case 12: per unit from
¥10,000–100,000
to ¥2 million–9 million
Stakeholders
National and local government, housing
developers, community, etc.
Required above-ground space
Case 12: Small household plots to 14.5 ha
Storage capacity
Case 12: Public rainwater harvesting system (RHS): 9,374 m³,
private RHS: 14,292 m³, community RHS: 283 m³,
household RHS: 61 m³

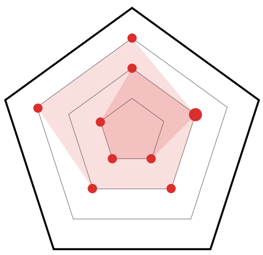
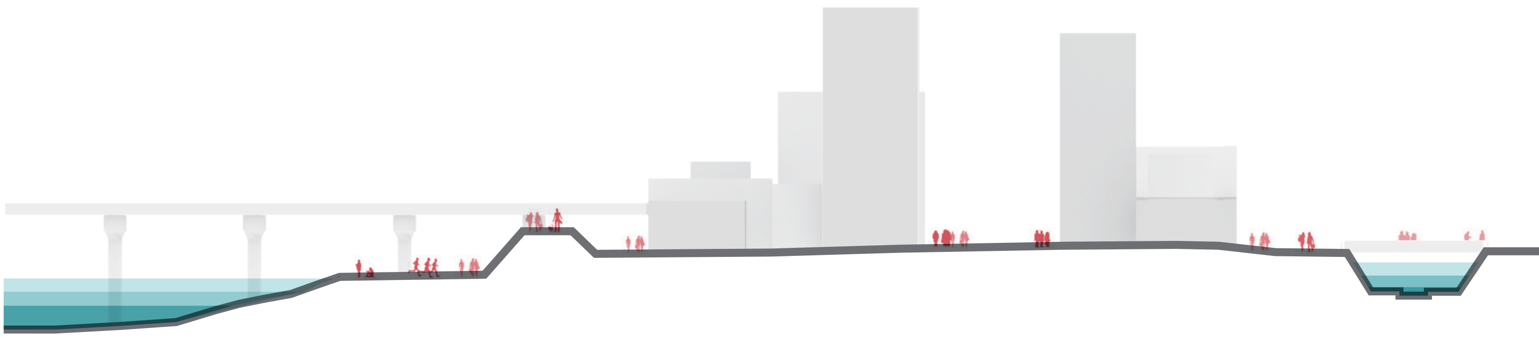
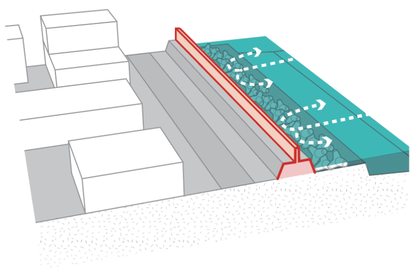

Additional benefits
Urban development, environmental sustainability, and DRM
Cost
Case 14: ¥256 billion
(Combined cost of urban development
and land readjustment projects)
Case 15: Construction: ¥1.8 billion
Stakeholders
Local government, housing developers, etc.
Required above-ground space
Case 15: 2.3 ha for public park
Storage capacity
Case 15: 1 m³ of substrate (consisting of stormwater storage
macadams and humus) has the capacity to hold 76 liters of water

 Figure 1, continued from previous page



Seawalls and gates

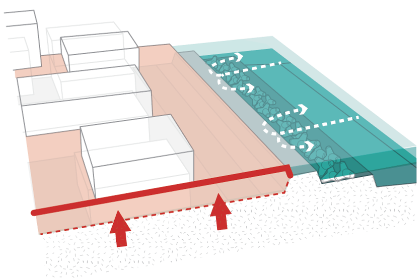


Case 19

Managing Storm Surge Flood Risk by Enhancing Seawalls and Flood Gates:

Port of Kobe

Ground raising



Case 20

Reducing Storm Surge Flood Risk by Raising the Ground Level:

Minato Mirai 21 District in Yokohama City

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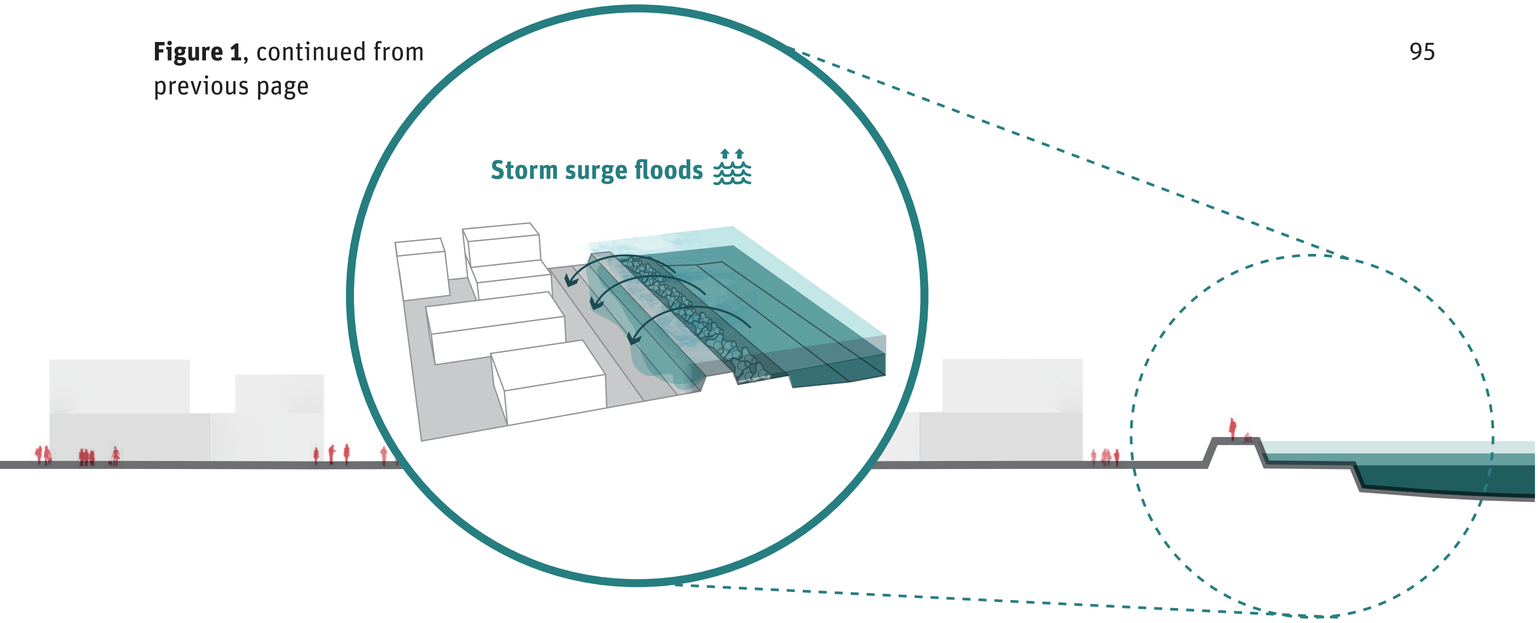

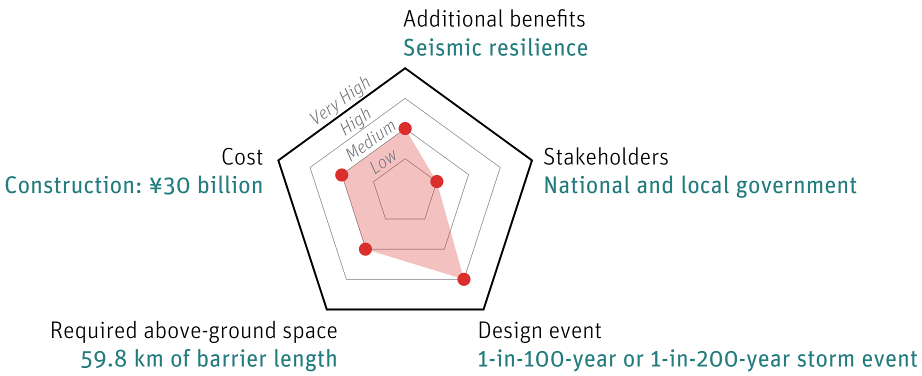

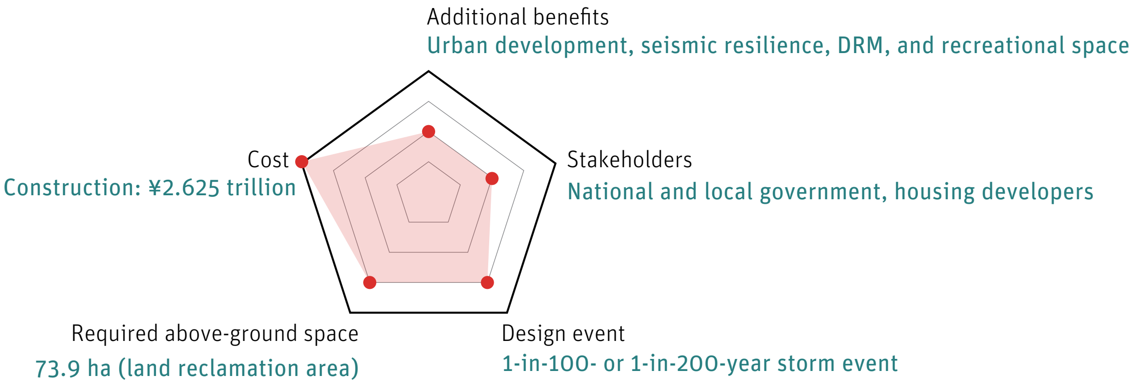

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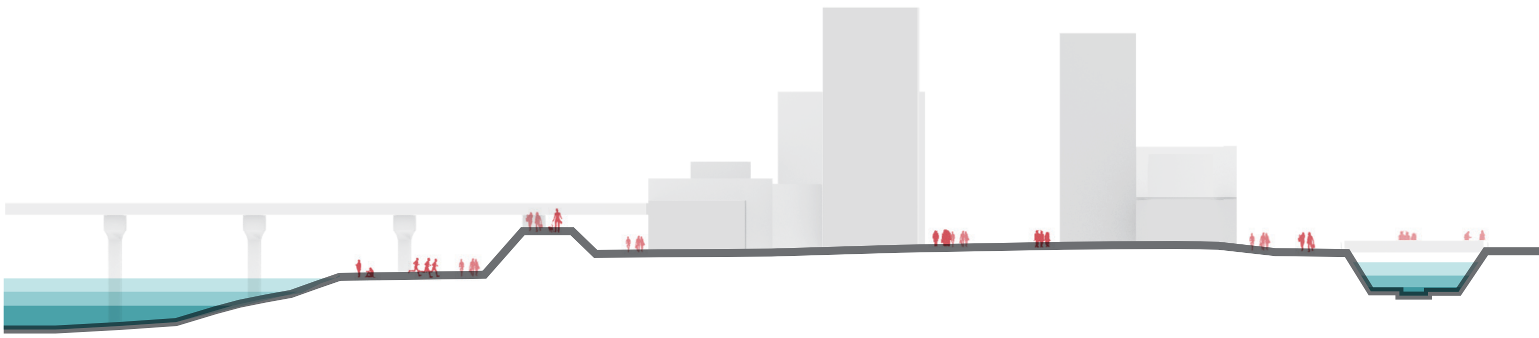
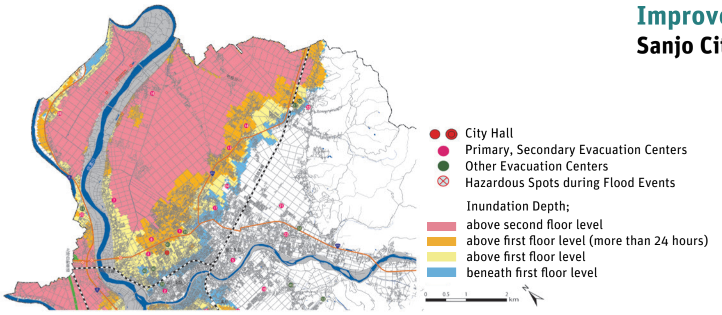


Risk assessment, land use plans, zoning, and building codes



Refer to Knowledge Note 1: Box 3

Flood Evacuation Plans in Sanjo City— Assessing Risk to Improve Citizens' Decision-Making Process:
Sanjo City, Niigata Prefecture

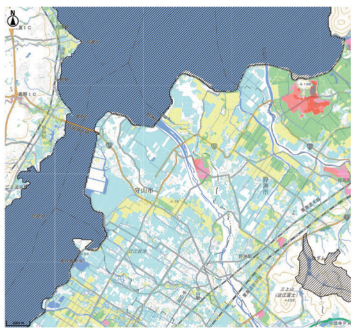
Enhancing early warning systems

Refer to Knowledge Note 1: Box 6

Disseminating Flood Risk Information—The "Timeline" Method Used by Urban Railways: Japan Railway (JR) West

Improving evacuation, drills, and awareness raising

1-in-100-year Rainfall

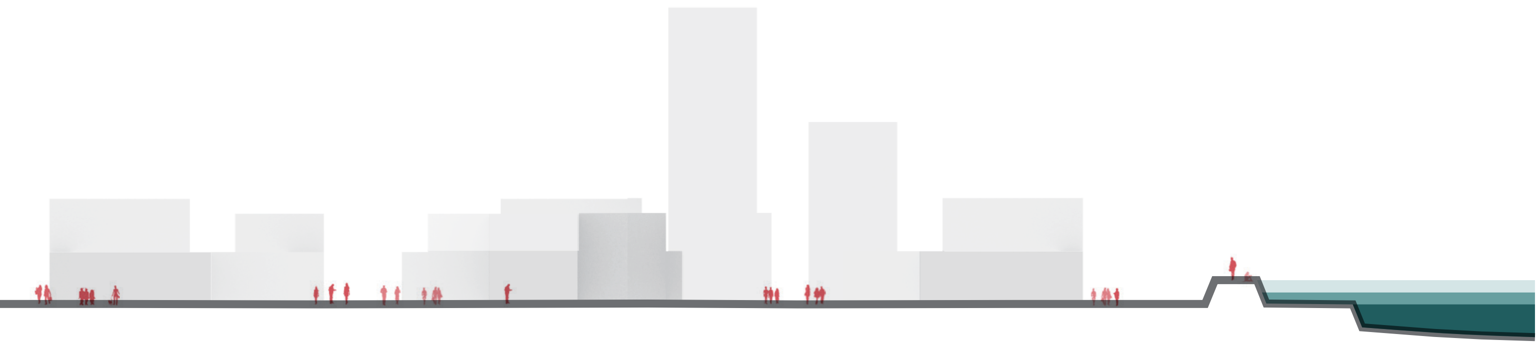


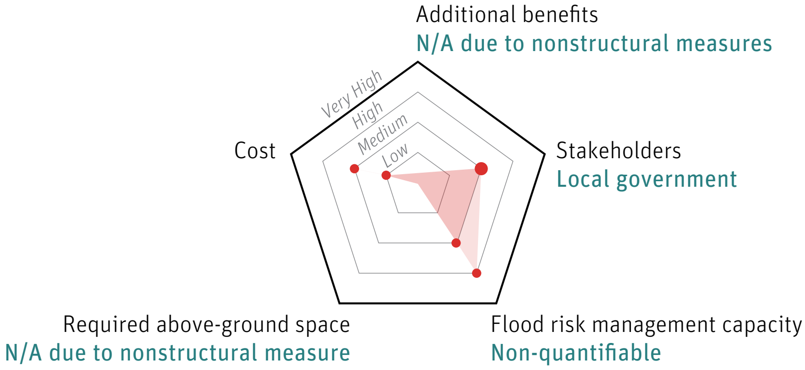
1-in-200-year Rainfall

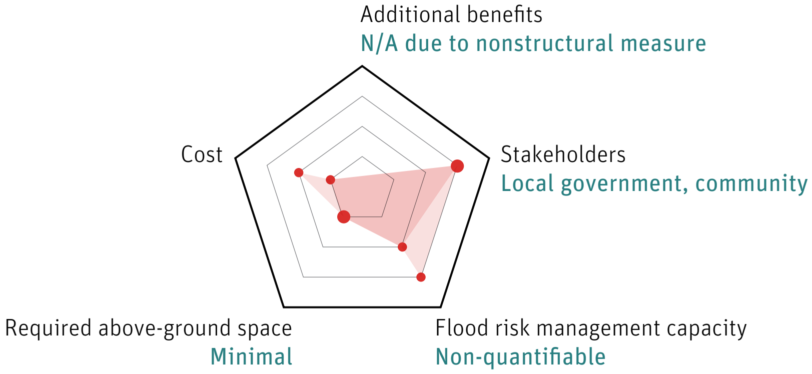
Indundation zones estimated;
less than 0.5m in depth
0.5 - 1m
1 - 2m
2 - 3m
3 - 4m
4 - 5m

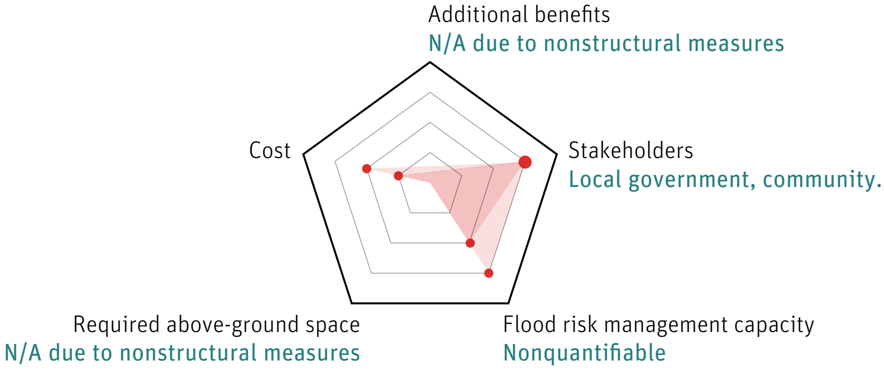
Refer to Knowledge Note 1: Box 4

Neighborhood Safety Maps in Shiga Prefecture—Using Risk Assessments to Raise Awareness: Shiga Prefecture









Note: DRM = disaster risk management; ha = hectare; km = kilometer; km^2 = square kilometer; m^2 = square meter; m^3 = cubic meter; mm = millimeter; N/A = not applicable; O&M = operation and maintenance; ¥ = Japanese yen.

3.1 Managing River Flood Risk

River Embankments

River embankments are generally large-scale structural investments designed to protect against floods from significant river overflow, such as that due to rainfall levels with a likely frequency of once in 150 to 200 years for large rivers and once in 100 years for medium-sized rivers (NIED 2009). Given their scale, embankments require substantial financing, space, and time. Because of their high cost and complexity, in Japan, their construction is normally led by national or municipal governments, with the objective of protecting urban centers with highly concentrated populations and assets from severe economic and social damages.

Many large river embankment investments have been **implemented together with urban redevelopment initiatives.** For example, the **Komatsugawa High-Standard Embankment** (appendix, case 1) in east Tokyo was developed by MLIT to reduce significant risks of damage to lives and assets from river floods in the Tokyo Metropolitan area, as well as to provide higher ground for evacuation in the Komatsugawa District. Given its high cost (approximately ¥48.8 billion [$444 million] as of 2011) (MLIT 2011) and required land area, the embankment's construction was implemented in conjunction with an urban redevelopment initiative led by TMG and Edogawa Ward and the Urban Renaissance Agency (UR). This example shows how large-scale, structural river management investments can leverage **a multipurpose design**, whereby not only flood management benefits are derived from the investments but also **additional benefits** such as disaster resilience and urban redevelopment.

Similarly, the redevelopment of the **Futakotamagawa** riverside area in western Tokyo is an initiative implemented jointly by the public sector (TMG and Setagaya Ward) and private sector partners (Tokyu Land Corporation and Tokyu Corporation). Here, a disaster-resilient and environmentally friendly commercial and residential redevelopment project was constructed alongside a high-standard embankment along the Tama River (appendix, case 2).

Underground River Overflow Management Facilities

Underground river overflow management facilities (cisterns, channels, etc.) are structural investments that require substantial financing and time for construction. Most are designed to manage floods likely to occur 1-in-20-year. Facilities installed in small- or medium-sized rivers in the Tokyo Metropolitan area (TMG n.d.[b], n.d.[c]) are built to withstand rainfall levels of 50–75 millimeters per hour (mm/hour).

Since they are constructed underground, the facilities do not require much land above ground for development. However, there is substantial financing, time, and coordination associated with underground construction. Because of its high cost and complexity, this construction is led by the national or municipal governments (depending on the size and designation of the river) in locations where there is an urgent need to protect highly concentrated populations and assets.

As such, investment in underground river overflow management facilities in Japan has been led by the public sector, which has made substantial efforts to **reduce costs and increase flood management impacts** (as discussed in **Knowledge Note 2**).

To achieve capacity targets as effectively as possible, **cisterns and channels to detain river overflow are often constructed under public land, such as roads and parks, to save land acquisition and compensation costs**. For example, TMG constructed a large-scale underground detention cistern underneath the publicly owned **Loop Road No. 7**, which saved significant costs and time (appendix, case 3). Furthermore, TMG often targets investments that can connect existing facilities, particularly channels, so that the overall flood management capacity can be increased by connecting separated facilities (TMG n.d.[b]).

River Overflow Management Facilities above Ground

River overflow management facilities located above ground (e.g., reservoirs, detention parks, and ponds) are developed near rivers at risk of overflowing. These structural, nature-based interventions have been adopted widely in Japan, over a long period of more than 100 years.[7] Large reservoirs, normally located adjacent to large rivers, also have a large flood management capacity. The cost of construction can be extremely high depending on the size of the facility, ownership of the land (and associated cost of acquiring the land), and whether the site already functions as a natural water detention site (as this may leave less construction work for flood management functions).

Large-scale reservoirs have been developed by MLIT and managed by local government or civil society organizations. Many also function as recreational parks or environmental conservation areas, such as the Ramsar sites[8] (Ministry of Environment 2018). They thus represent the significant efforts made in Japan to promote **multibenefit and multipurpose** designs, bringing together river and environmental departments and stakeholders in the construction and management of the facilities.

The **Arakawa River No. 1 Detention Park** (appendix, case 4) in Saitama City, located near Tokyo, not only stores up to 39 million cubic meters (m^3) of floodwater—which could protect nearby urban areas from inundation during a 1-in-200-year flood event—but also functions as a recreational facility and drinking water reservoir for residents of Saitama and Tokyo, cushioning water shortages during dry periods.

In the case of the **Myoshoji River** (appendix, case 5), which flows between the Shinjuku and Nakano wards in central Tokyo, local governments in partnership with TMG and UR (a housing developer) have developed a multipurpose residential development (led by UR), together with a detention pond (led by TMG) and a public park (led by the Shinjuku and Nakano wards). The total development area is approximately 11,000 square meters (m^2) with a water detention capacity of approximately 30,000 m^3. This coordinated approach has enabled the sharing of roles and responsibilities, leading to cost savings in implementation and O&M.

3.2 Managing Surface Water Flood Risk

Underground Stormwater Management Facilities

Similar to underground facilities for managing river overflow, **underground stormwater management facilities (cisterns, channels, drainage pipes, culverts, etc.) are structural investments that require substantial financing and time for implementation.** In Japan they are typically designed to manage 1-in-20-year floods, in line with MLIT and city-level stormwater management targets (as described in **Knowledge Note 2**).

Since the facilities are constructed underground, they do not require much space above ground, but the cost and time of underground construction is extremely high, and the **stakeholder and political coordination** associated with it is complex. Therefore, development of underground stormwater management facilities is usually led by municipal governments, given their responsibility for urban drainage and sewerage management in Japan. Such facilities are most often found where there is a strong need to protect highly concentrated populations and assets, supported by financing and technical guidance conducted in close coordination with the national government.

Because of the associated cost and complexity, cities in Japan have trialed **various cost-saving and partnership approaches** in the design and implementation of underground stormwater management facilities. In Tokyo, up to 50 mm/hour rainfall is managed through channels and pipes that tend to drain water quickly to larger rivers and the ocean. However, with a recent change in surface water flood management goals, which increased to 75 mm/hour rainfall, TMG is looking to add capacity to existing drainage facilities.[9]

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7 For example, the Watarase reservoir that protects the Tokyo Metropolitan Area from flooding was initiated in 1914. For more information, see http://www.watarase-kyougikai.org/history/index.html.

8 The Convention on Wetlands, called the Ramsar Convention, is an intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources. The convention maintains a List of Wetlands of International Importance (the Ramsar list). These Ramsar sites acquire a new national and international status. They are recognized as being of significant value not only for the country or the countries in which they are located, but for humanity as a whole. There are currently over 2,300 Ramsar sites around the world. They cover over 2.1 million square kilometers, an area larger than Mexico. For more information, see https://www.ramsar.org/about/wetlands-of-international-importance-ramsar-sites.

9 For more information, see TMG (2015).

Managing surface floods can be challenging in dense urban areas where there is significant development both above and below ground (metro, utility lines, commercial areas, etc.). **TMG has utilized innovative technologies** in the construction of its underground water detention channels: the application of the "shield method" enables channels to be constructed in dense underground spaces with high accuracy and speed but with low sound and tremor impacts to the surrounding areas (appendix, case 6).

Similarly, **TMG has added underground stormwater storage to other public facilities, to reduce costs of constructing extra facilities**. For example, in Minamisuna, TMG constructed a detention pond 20 meters below ground with a storage capacity of 25,000 m^3, with a public housing complex, public bicycle parking, and a park developed above ground as part of the larger urban Shinsuna Land Readjustment Project. In Hibiya, TMG, in partnership with MLIT, constructed a detention pond with a storage capacity of 3,400 m^3 under a common lifeline infrastructure tunnel[10] that runs beneath a national road (appendix, case 7).

Yokohama City has partnered with private sector developers to develop underground stormwater management facilities in conjunction with an urban redevelopment initiative at Yokohama Station. Under MLIT's designation of Yokohama Station and its vicinity as the first "Flood Mitigation Focus Area" in Japan, MLIT, Yokohama City, and the East Japan Railway Company (JR East, the developer) shared costs and responsibilities of installing a 170 m^3 underground stormwater management facility within the new Excite Yokohama 22 District development project. MLIT and Yokohama City each financed one-third of the stormwater management facility's construction costs through subsidies, and JR East self-financed the remaining costs. All stakeholders benefited from this joint effort (appendix, case 8).

Above-ground Stormwater Management Facilities

Stormwater management facilities located above ground (such as detention ponds, parks, and gardens) are structural, often nature-based, measures that detain stormwater during heavy rain before it is released to drains and rivers. They are often constructed together with urban development initiatives to ensure that additional stormwater is not drained into sewerage systems due to new construction. Such facilities contribute to managing 1-in-20-year floods, in line with MLIT and city stormwater management targets (as described in **Knowledge Note 2**).

The space required depends on the size of the facility and its associated capacity. Such facilities are often designed for **multiple purposes and uses**; for example, to also serve as public and environmental amenities such as parks, sports fields, biotopes, biodiversity conservation sites, etc. Therefore, **various stakeholders can be engaged** in the design, financing, and O&M of interventions, creating an opportunity to **share the costs and responsibilities of flood management** with actors beyond the public sector.

Saitama Prefecture has promoted the implementation of surface flood and river flood management measures, utilizing policy mechanisms to scale the establishment of detention ponds, parks, and gardens through both public and private efforts. To scale private sector efforts, Saitama Prefecture took the progressive approach of **requiring all new private development projects (commercial, residential, etc.) with an area of more than 1 hectare to install detention facilities.** This builds on the administrative guidance first released by the prefecture in 1968 under the national Urban Planning Act, which was then advanced as a requirement under an ordinance enacted in 2006 (Saitama Prefecture 2018). By 2014, over 170 detention facilities with a capacity over 10,000 m^3 were developed through both private and public efforts in Saitama Prefecture, of which 51 were aimed to detain water to avoid overflow into rivers, and 119 were to manage additional stormwater drainage from new developments (Saitama Prefecture 2018).

For example, **Koshigaya City** in Saitama Prefecture integrated flood management measures in a new, compact, 225-hectare urban development project from 1999 to 2014. The project was led by the Urban Renaissance Agency (UR), in close collaboration with Saitama Prefecture and MLIT. A large-scale reservoir (with 1.2 million m^3 water detention capacity over 39.5 hectares) was established as part of the development, to manage both river and surface water floods. **Costs and responsibilities for its construction and O&M are shared** by UR, Saitama Prefecture,

10 Lifeline infrastructure systems include interdependent and often colocated utilities (electric power, natural gas, telephone and other communication systems, water and wastewater) and transportation systems (roads and highways, rail systems, ports, and airports).

and MLIT.

Sewerage Treatment Facility Improvements

Enhancing sewerage treatment facilities' capacity to detain stormwater is an important urban flood management measure. It not only reduces potential inundation from overflow, but also reduces urban water pollution. Combined sewer systems, in which both rainwater and wastewater are conveyed and treated in a single channel, serve around 25 percent of the population and 13 percent of a total of 1,430 municipalities with wastewater services in Japan (JSWA 2017). Older cities with high urban densities are often served by combined systems, and as a result, during heavy rain, the discharge of untreated water is of serious concern for public health and the environment. For example, 82 percent of the central wards of Tokyo are serviced by a combined sewer system (appendix, case 16). However, the enhancement of structural sewerage treatment facilities is costly given its significant time and land requirements.

In light of these factors, several Japanese cities have set up strategic partnerships with various stakeholders to implement sewerage enhancement and upgrading efforts. For example, the **Shibaura Wastewater Treatment Plant** (appendix, case 11) has been responsible for sewerage water treatment in Tokyo, including the Chiyoda, Chuo, and Minato wards, since 1931. Beginning in 2012, renovation of the aging facility was undertaken in stages, with two objectives: (i) to mitigate the postflood environmental impact of the combined sewerage and drainage system, and (ii) to effectively utilize the high land value of the facility's locations. TMG, the owner of the 11,000 m^2 area occupied by the Shibaura Water Treatment Plant, tendered for a private sector firm that would redevelop the area under a 30-year lease agreement, as well as renovate the water treatment plant, including constructing a combined sewer and stormwater detention facility with a capacity of 76,000 m^3 under the developed land. Through the privately financed initiative, a 32-story commercial and office building (Shinagawa Season Terrace), as well as a publicly accessible park were developed, together with the upgraded wastewater treatment plant and detention facilities. TMG continues to recover the lease fee through a land-value capture mechanism, whereby the income generated through maintaining ownership and leasing 60 percent of the newly constructed building is retained by TMG. The generated income is utilized by TMG for O&M of the sewerage facility.

Rainwater Harvesting Systems

Rainwater collection systems and storage tanks installed in public, commercial, and community buildings are structural measures. The storage tanks may be visible (e.g., on building rooftops) or underground. These systems may be integrated with others for the use of the collected water (e.g., pumps or piping systems to use collected water for toilets, etc.). In Japan, the 2014 Act to Advance the Utilization of Rainwater, together with the "Technical Standards for Rainwater Harvesting," published in 2016 by the Architectural Institute of Japan Environmental Standards, were established to advance and scale rainwater harvesting systems, as well as set basic guidelines for their technical design and the use of collected water. Currently, the act limits utilization of the harvested rainwater to toilets and the watering of plants (MLIT 2015).

The capacity of stormwater management varies depending on the size of the collection and storage facilities and can range from small household systems, such as 150-liter planters that are connected from household roofs through downspouts, to tanks with total storage capacity of 2,635 m^3 (Tsukahara and Okagaki 2012) installed under the Tokyo Skytree commercial development in eastern Tokyo. The costs and time required for construction and O&M also vary depending on the size of the systems.

Together with MLIT, which governs the 2014 act, city governments in Japan promote rainwater harvesting systems widely. Many local governments have installed rainwater harvesting systems in their public buildings. Others also advise (but do not require) new development projects to install facilities to manage stormwater generated on site. To support these efforts, many local governments offer subsidy programs (such as in Sumida Ward, further described in the appendix, case 12).

Rainwater harvesting systems are regarded as a major flood management measure in cities, especially in urban areas that are located inland with limited infiltration capacity, since they are more cost-effective than many other flood management measures. For example, in Sumida Ward, Tokyo, rainwater harvesting systems have been adopted widely by public, private, and community groups, and in households, and are regarded as "urban dams." While the rainwater harvesting capacity of each household may be small, the total contribution from household rainwater harvesting and storage systems toward reducing stormwater runoff is collectively significant. In 2008, 21 Rojisons[11] were installed in Sumida Ward (Sumida Ward 2018a); by March 2018, there were 645 facilities with a capacity of 24,010 m^3, equivalent to approximately 90 liters of rainwater per ward resident (Sumida Ward 2018b).

Also, in Sumida Ward, the installation of a large-scale rainwater harvesting system in Tokyo Skytree by a private developer illustrates how the private sector can catalyze innovative design. Tokyo Skytree Town was a high-profile redevelopment initiative led by the Tobu Railway Company between 2008 and 2012, to revitalize a flood-prone neighborhood in eastern Tokyo along with the construction of a new 634-meter-high broadcast tower that serves as a new landmark for Tokyo. As a key feature of the Skytree Town development, the Tobu Railway Company, the private developer, in close consultation with ward authorities, implemented progressive rainwater harvesting and utilization measures, together with various green and environmental initiatives as part of its **corporate social responsibility** and branding strategy. An 800 m^3 rainwater harvesting tank and an 1,835 m^3 underground stormwater detention cistern were established to manage not only stormwater generated on site, but also for the surrounding community. Furthermore, collected water was recycled to cool buildings and solar panels, water rooftop gardens, and flush toilets. With the installation of this system, an estimated 45 percent of water consumption was saved. Other innovative water and environmentally sensitive projects were implemented throughout the surrounding areas, including efforts led by Sumida Ward, such as a public bicycle park that combines rainwater harvesting and renewable energy features to create an attractive public green space.

Increasing the Permeability of Urban Surfaces

Enhancing the infiltration capacity of urban surfaces through their conversion into green spaces or installing pervious pavers and infiltration trenches are structural measures that aim to manage urban flood risk by minimizing the volume of drainage during heavy rain. Measures to modify the surface composition of the catchment from impervious to pervious require relatively little financial resources, time, and space. They are often implemented in conjunction with or as part of an urban redevelopment project or the maintenance and rehabilitation of roads or public spaces, and are installed so as to derive **multiple benefits.** Such benefits include the integration of green public and living spaces, as well as **year-round functions** such as heat reduction and/or drought management.

In **Hachioji Minamino City**, mechanisms for water circulation were key features of a 39.4 hectare town development and land readjustment project carried out by UR. The developer and the city, together with community and academic research partners, established a water circulation and restoration system to enhance and protect groundwater resources, along with other structural and nature-based flood management measures such as detention ponds. Homeowners were encouraged to install **household stormwater infiltration facilities** through a city-run awareness-raising campaign and subsidy program, which supported 90 percent of households' total installation costs. Data collected on the infiltration capacity of Hachioji Minamino City between 1996 and 2013 indicate that the installation systems were highly effective in minimizing stormwater runoff during the wet season as well as mitigating drought during the dry season (appendix, case 14).

Both public and private sector efforts have been instrumental in advancing measures to enhance the infiltration capacity of Japanese cities. For example, **the City of Yokohama,** through its effort to renovate **Grand Mall Park**, a 25-meter-wide, 700-meter-long pedestrian corridor, integrated a "vertical water circulation" mechanism whereby stormwater infiltrates the pervious pavement and circulates through a system of infiltration gutters, stormwater storage macadams, and planting beds. One cubic meter of substrate (consisting of stormwater storage macadams and humus) has the capacity to hold 76 liters of water. Given the park's location in front of the Museum of Art, it serves as an important public space. Since the space suffered from overheating during summer, the city chose to install a system that not only infiltrates stormwater to manage flooding, but also can release water moisture in the air during the dry and hot seasons, to cool the air and enhance the microclimate of the park. After the system's installation, the air temperature of the Grand Mall Park dropped significantly (appendix, case 15).

11 An underground, community-owned, rainwater detention facility. For more information, see appendix, case 12.

3.3 Managing Storm Surge Flood Risk

Seawalls and Gates

Seawalls and tide gates are large-scale structural measures installed along coastlines to protect people and assets from storm surge floods. Given the high seismic risks, most Japanese cities have designed seawalls and tide gates to protect against storm surge floods and tsunamis. As the risk of unforeseen natural disasters rises, including both climatic (i.e., typhoons and heavy rains) and seismic episodes, the continuous enhancement and expansion of these coastal investments is important, in terms of both infrastructure design and operation. Most seawalls and gates extend over many kilometers, thus requiring significant time and financing, and are often implemented in partnership between the city and national government stakeholders.

Given these high construction and O&M costs, **many cities have taken an incremental approach to the development and improvement of their coastal flood management methods, and have applied innovative technology to enhance their operations.** For example, as one of Japan's major port cities facing significant risks of coastal floods, **Kobe City** has been implementing a storm surge protection project (costing approximately ¥30 billion, or $273 million) for more than five decades, through investing in flood management infrastructure across its 59.8-kilometer coastline. Seawalls and iron tide gates were set up in coastal areas to prevent seawater from overflowing due to storm surges. Pump stations were installed to pump seawater out from the urban areas at the time of storm surges. Nonstructural measures, such as: (i) strengthening the predisaster prevention system in areas of high flood risk by encouraging the development of business continuity plans; and (ii) enhancing early warning systems and the provision of disaster prevention information to residents and workers in coastal areas were also adopted to also ensure that preparedness and response actions are implemented in conjunction with structural measures. The city, in partnership with MLIT and academia, has regularly reviewed the strengths and weaknesses of the investments, particularly after major disaster events, such as the 2011 Great East Japan Earthquake (GEJE) and the 2018 Typhoon Jebi. After these major events, ways of addressing bottlenecks and prioritizing investments were identified. For example, learning from the experience of the GEJE, when more than 59 lives were lost or went missing as people attempted to close the tide gates, technologies to remotely operate the tide gates are being implemented. There are plans of linking the system to tsunami early warning systems that can automatically close these gates in times of disaster. After Typhoon Jebi, Kobe City planned to implement recommendations made by a technical panel, including structural measures such as ground raising and fortification of seawalls in targeted areas, to improve disaster information communication systems and the O&M of coastal embankments (appendix, case 19).

Ground Raising

Ground raising is a structural measure to protect urban areas against storm surge floods as well as tsunamis. Given its relatively large requirements for space, investment, construction time, and coordination efforts (involving complex land readjustment and relocation of preexisting structures), it is typically implemented together with urban (re)development initiatives led by city governments and large-scale private developers in Japan. Developments on raised ground serve as new economic and commercial hubs, as well as disaster risk management hubs for the surrounding areas, providing an important safe ground where critical infrastructure and utility functions as well as evacuation centers can be located to reduce disaster risks.

For example, the **Minato Mirai 21 (MM21) district is a 183-hectare, master-planned urban development project in Yokohama City developed by UR in partnership with the City of Yokohama between 1983 and 2011.** The project included the reclamation of a 74-hectare site, using a sand-draining method for ground stabilization, and the construction of utility tunnels under arterial roads. Disaster risks, including those of earthquakes, tsunamis, and storm surge floods, were taken into consideration in the design and implementation of the land reclamation and development process. For example, learning from the 1995 Hanshin Awaji earthquake, land improvements and measures against liquefaction were implemented. As measures against tsunamis and storm surges, revetments along the coast were constructed at a height of 2.7–3.1 meters above sea level, and residential developments were required to be developed in areas 3.1–5.0 meters above sea level in the central districts of MM21.

Despite the high costs and significant time required for the development of the MM21 district, the City of Yokohama reports significant economic benefits. Construction costs—estimated at ¥2.625 trillion ($23.9 billion) from 1983 till 2016—have been fully recovered. MM21 attracted more than 1,800 companies and 83 million annual visitors in 2019, yielding a tax income of more than ¥14.5 billion ($132 million) to the city in just that year (City of Yokohama 2019). Importantly, the city was able to also enhance its overall disaster risk management capacity by providing access to disaster-resilient land, utilities (including a decentralized heating and cooling system), ports (which can serve as logistical centers for emergency response operations), and an emergency water storage capacity of 4,500 m^3, which can supply safe drinking water for 500,000 people for three days (City of Yokohama n.d.). **The MM21 district demonstrates how structural and nonstructural storm surge flood measures can be integrated within large-scale coastal redevelopment projects from the design phase to implementation, and how these resilience measures can generate significant economic, environmental, and social benefits.**

Further details on this example (case 20) are included in the appendix.

3.4 Managing Multihazard Risk

Together with the structural measures for urban flood risk management described above, nonstructural measures are essential in ensuring that lives and livelihoods are protected, especially under increasing risks of extreme and unprecedented disaster events. A variety of nonstructural measures have been implemented in Japanese cities to enhance flood management through a multihazard approach, by avoiding development in flood-prone areas, guiding flood-resilient construction development, and improving evacuation through improving the communication of flood risks as well as enhancing the awareness and capacity of citizens to take effective preparedness and response actions after receiving risk and warning information.

Knowledge Notes 1 and **2** elaborate on these nonstructural flood management measures. **Table 1** lists the types of measures and the examples referenced in **Knowledge Notes 1** and **2**.

Table 1: Nonstructural Measures and Examples from Japanese Cities

Measures	Example	For more information
Risk assessment, landuse plans, zoning and building codes	Shiga Prefecture	Knowledge Note 2: 4.2 Case of Shiga Prefecture (integrating flood risk information into land use regulations)
	Sanjo City, Niigata Prefecture	Knowledge Note 1: Box 3. Flood Evacuation Plans in Sanjo City—: Assessing Risk to Improve Citizens' Decision-Making Process
Enhancing early warning systems	Tokyo Metropolitan Government	Knowledge Note 1: Box 5. Integrating Climate Change into Hazard Maps—: Regional Evacuation Plans for Large-Scale Floods in Tokyo
	Japan Railway (JR) West	Knowledge Note 1: Box 6. Disseminating Flood Risk Information—: The "Timeline" Method Used by Urban Railways
	Tokyo Metro	Knowledge Note 1: Box 7. Disseminating Key Information through Multiple Means: The Case of Tokyo Metro
Improving evacuation, drills and awareness-raising efforts	Shiga Prefecture	Knowledge Note 1: Box 4. Neighborhood Safety Maps in Shiga Prefecture—: Using Risk Assessments to Raise Awareness
	Tokyo Metropolitan Government	Knowledge Note 1: Box 5. Integrating Climate Change into Hazard Maps—: Regional Evacuation Plans for Large-Scale Floods in Tokyo
	Sanjo City, Niigata Prefecture	Knowledge Note 1: Box 8. Evacuation Measures for Those in Need of Assistance in Sanjo City

Source: Compiled from Knowledge Notes 1 and 2.

4. Lessons Learned and Key Takeaways

Based on the case studies discussed in this Knowledge Note, several lessons and takeaways can be identified related to the various processes that inform the design and implementation of urban flood risk management investments.

Multiple factors and criteria drive the design process. Overall objectives are determined based on the types of flooding, and the target flood risk management capacity to be achieved. Spatial and financial requirements determine the type and scope of investments, which are also linked to the institutional level and type of the public entity overseeing the investments. Technical considerations, including data gathered via surveys and assessments, determine feasibility and guide the entire design process. Increasingly, schemes are designed to be multifunctional and generate multiple urban, social, and environmental benefits. Green or nature-based solutions are a case in point.

Focusing on cities, this Knowledge Note looks at the implementation of investments to manage the risk of river floods, surface floods, storm surge floods, and a combination of these types of floods. Examples across Japan illustrate efforts to engage the private sector and local communities, and the benefits of utilizing new technologies, nature-based solutions, and financing arrangements with the private sector.

- **River floods.** Common interventions in Japan to tackle river floods include river embankments, underground river overflow facilities, as well as reservoirs, detention parks, and ponds. **Tokyo City's Komatsugawa** High-Standard Embankment or **Futakotamagawa** riverside area demonstrate how large-scale, structural river management investments can be designed to have multiple purposes and benefits. The same is true of reservoirs and detention parks, as in the cases of the **Arakawa River No. 1 Detention Park** and **Myoshoji River.** Though underground river overflow management facilities can require substantial financing and time for construction, they can be helpful where available land is scarce. Examples from **Tokyo City** show that cisterns and channels can be constructed under public land such as roads and parks to save land acquisition and compensation costs.

- **Surface floods.** Common interventions include cisterns, channels, drainage pipes, culverts, stormwater detention ponds, parks and gardens, sewerage treatment facilities, as well as rainwater harvesting collecting and storage systems, and surface infiltration measures. Above-ground stormwater management measures depend on the space required, and are often designed for multiple purposes and uses, with many stakeholders involved beyond the public sector. In order to scale private sector efforts to tackle surface floods, **Saitama Prefecture** mandates all new private development projects (commercial, residential, etc.) with an area of more than 1 hectare to install detention facilities. Enhancing the stormwater detention capacity of sewerage treatment facilities helps to mitigate urban flood risk, while reducing water pollution. To manage costs, an upgrade of the **Shibaura Wastewater Treatment Plant's** stormwater detention capacity was combined with a private-financed initiative that included a 32-story commercial and office building, and a park. The lease fee, through a land-value capture mechanism, generates income used by the authorities for the O&M of the sewerage facility. Rainwater harvesting systems are widely promoted in Japan, and many local governments having installed them in public buildings. **In Tokyo**, both small-scale, community-led, as well as large-scale, private sector–led rainwater harvesting efforts are ongoing. The implementation of green spaces or pervious pavers and infiltration trenches can be combined with urban redevelopment or maintenance efforts to save costs. For example, **the Grand Mall Park in the City of Yokohama** integrated a "vertical water circulation" mechanism combined with the release of water moisture into the air, increasing infiltration capacity while cooling the air temperature of the area. A new development in **Hachioji Minamino City** includes a water circulation and restoration system, and a household-level campaign for the installation of stormwater infiltration facilities.

- **Storm surge floods.** A large number of Japan's cities rely on structural protection along the country's coastline, such as seawalls and gates, as well as ground-raising efforts. Cities such as **Kobe** invest heavily in structural solutions, and combine these with improved disaster information communication systems and improved maintenance efforts. Because ground raising can be complex due to the size, cost, time involved, and technical issues involving land readjustment and relocation, it is often implemented together with large-scale urban development initiatives led by city governments and large-scale private developers in Japan. For example, the **Minato Mirai 21** district benefited from a master-planned urban development project in **Yokohama City**, which included land reclamation, the use of the sand-drain method for ground stabilizing, and the construction of utility corridors under arterial roads. The city of **Yokohama** reports significant economic benefits after having fully recovered the investment, attracting companies and millions of annual visitors, while creating a seismic-, tsunami-, and storm-surge-resilient area within its urban center. This new evacuation hub features access to disaster-resilient land, utilities (including a decentralized heating and cooling system), ports (that can serve as logistical centers for emergency response operations), and a supply of emergency drinking water sufficient to last 500,000 people for three days (City of Yokohama n.d.).

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

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)

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),[1] 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

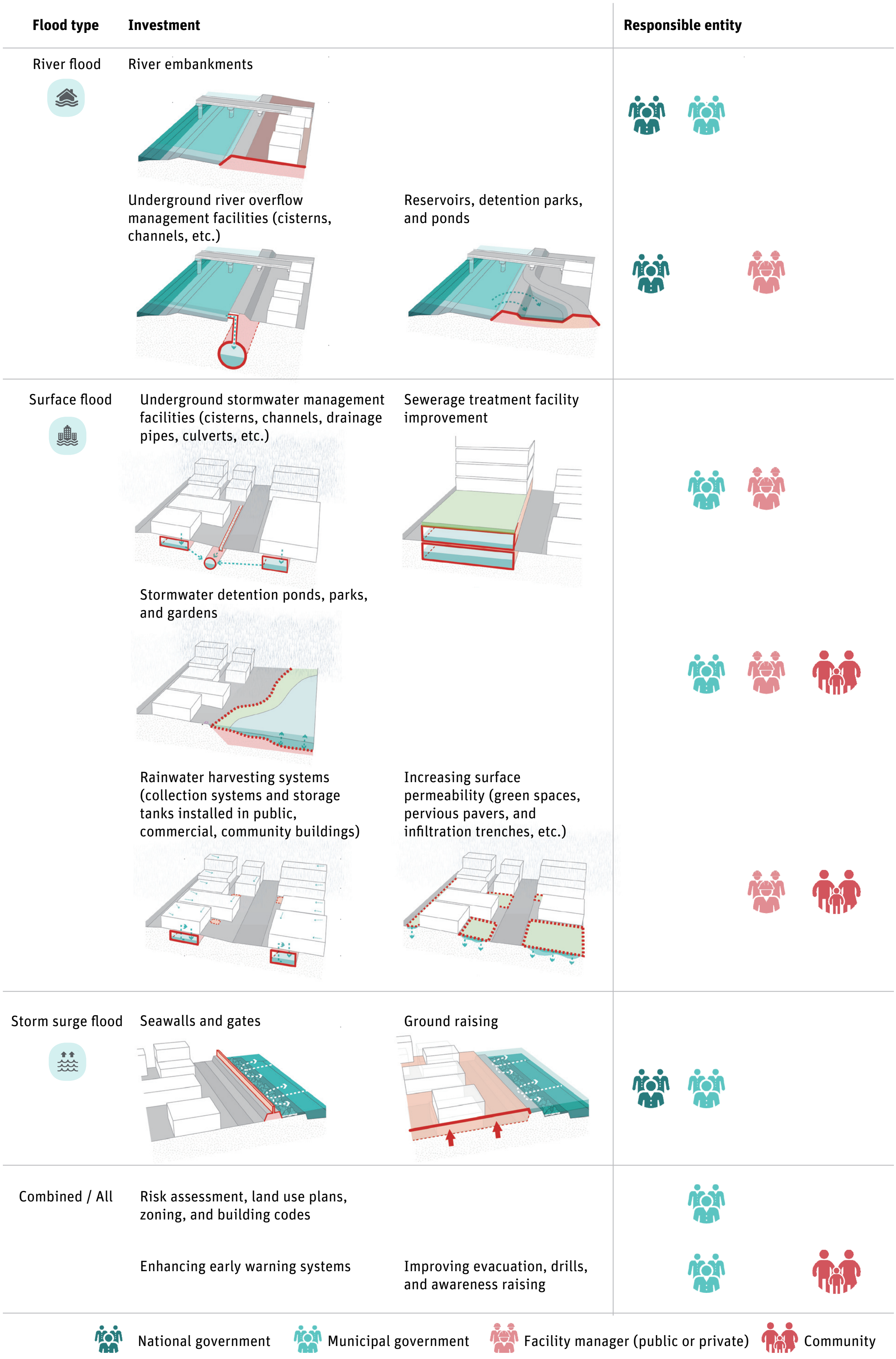
With a common goal of mitigating urban flood risk, Japan's national and local governments, private sector, and citizens share responsibility for the O&M needed to sustain IUFRM investments. Institutional roles and responsibilities for specific O&M tasks are delegated based on the context, including the 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.[2]

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

1 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.).

2 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



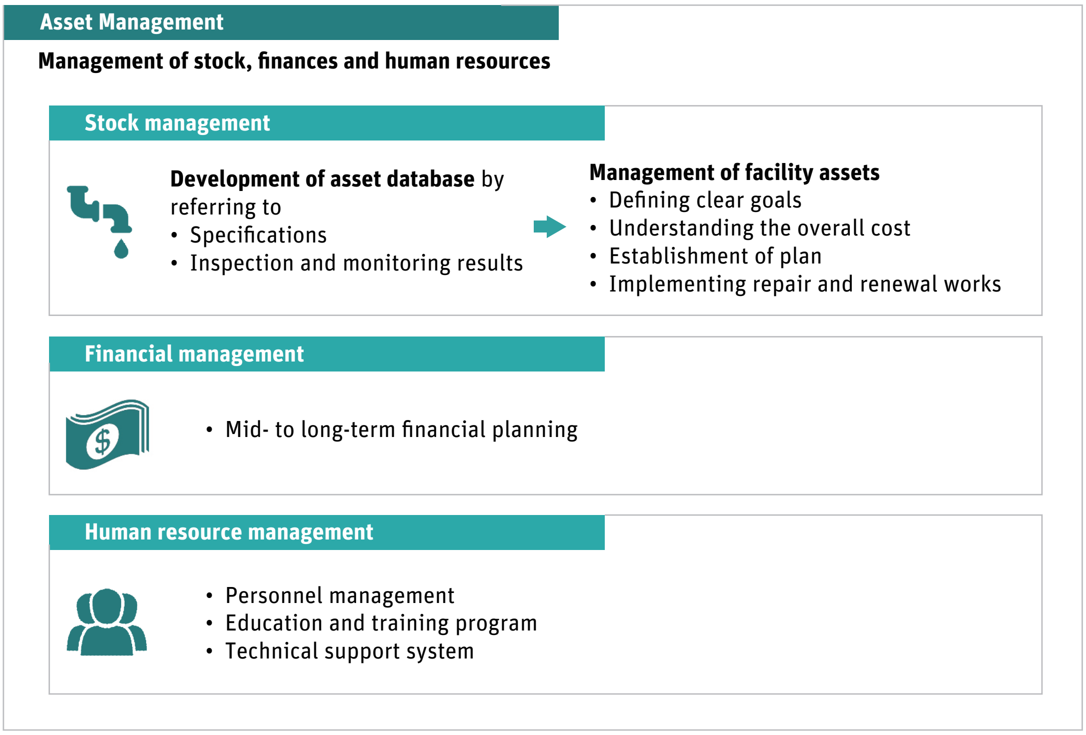
Sources: Authors' compilation.

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).

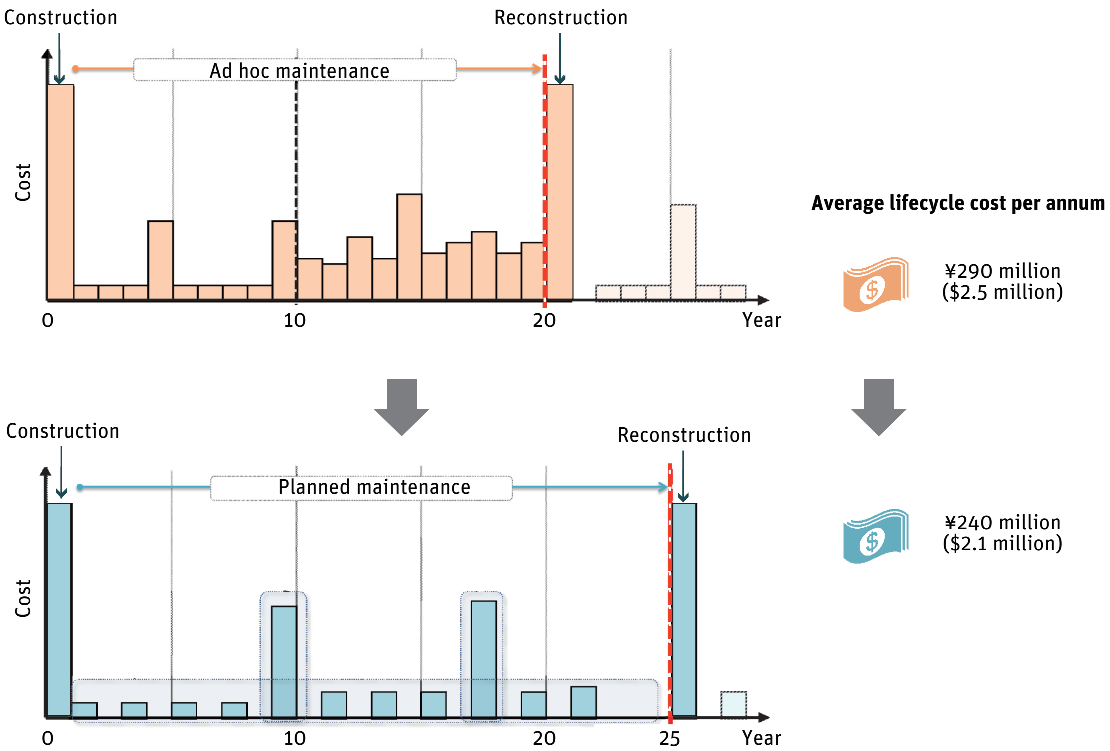
For example, for sewerage facilities, managing assets would entail examining the entire life cycle of facilities and equipment so that preventative maintenance can be implemented strategically from the planning and design stages. Property is maintained systematically and efficiently while considering 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[3]) 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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3 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:

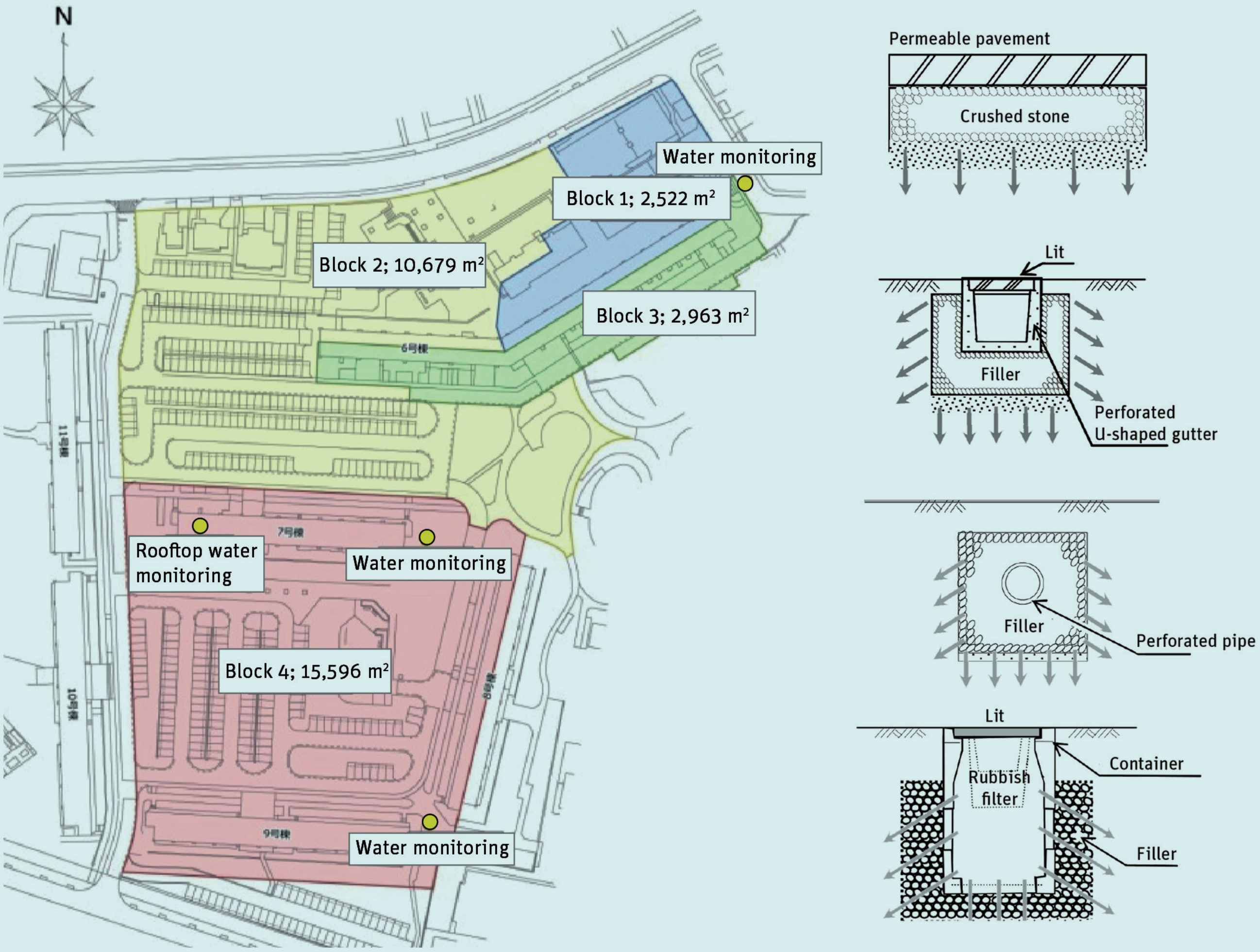
- **The infiltration facility sustained its flood management function over 20 years.** The runoff rate over 20 years remained at around 0.1 for the northern block (that is, with the intervention). Furthermore, its performance under short, concentrated heavy rain, as well as a long, larger total volume 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

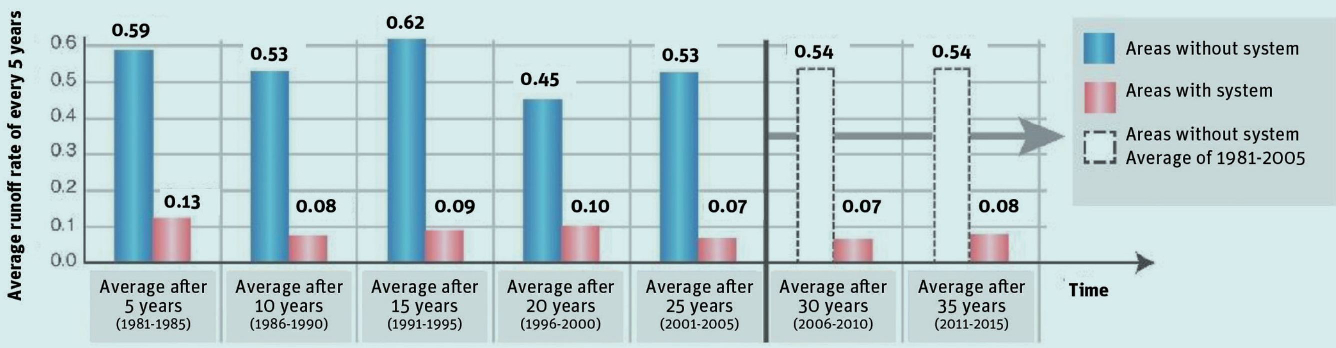


Source: Satomi 2013; Hayashi, Shimada, and Morikami 2002.
Note: m^2 = square meter.

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

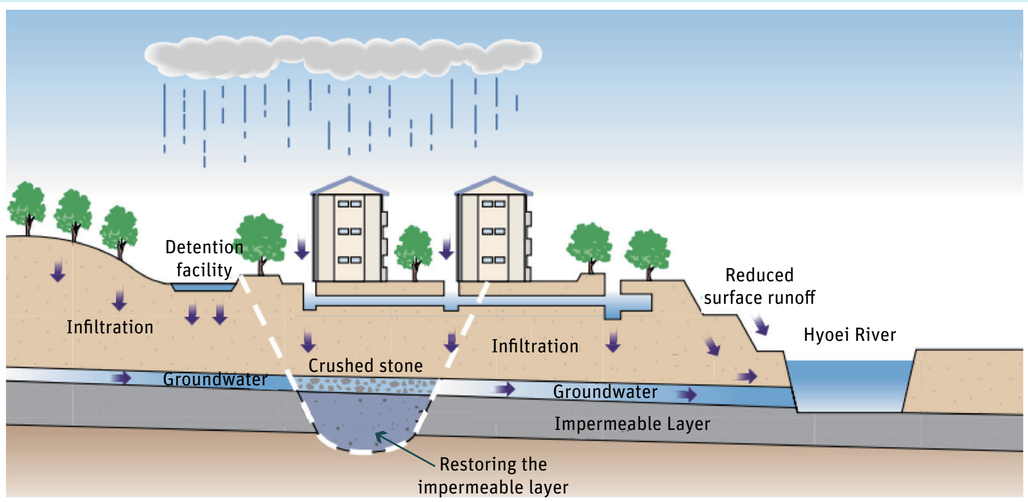
Similar to Akishima City, Hachioji Minamino City was developed as a new large-scale (394.3 ha) residential neighborhood to accommodate Tokyo's growing urban population between 1986 and 1997. When the project was proposed, significant concerns were raised by residents and the academic community regarding 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.

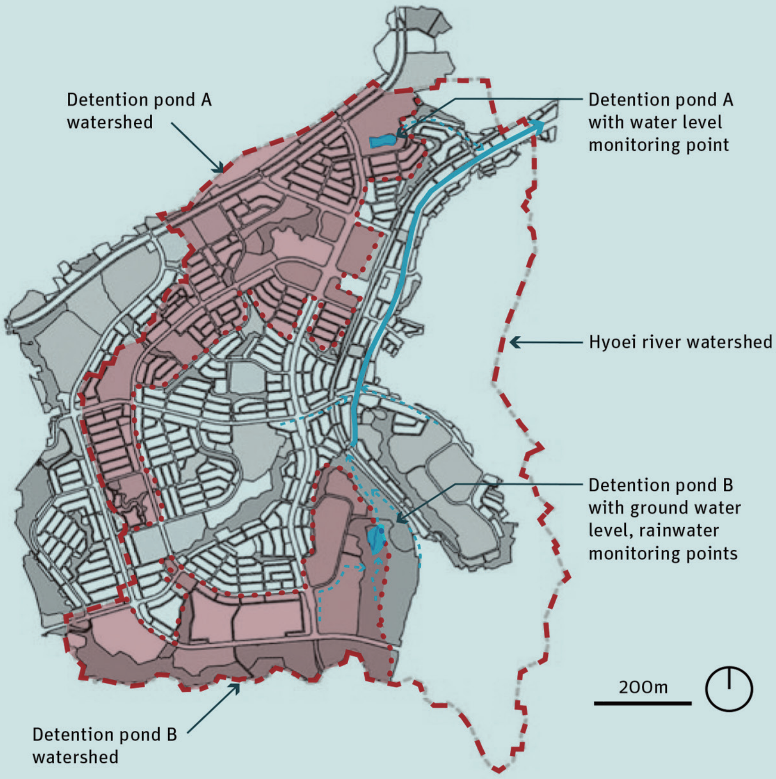
System objectives were threefold, touching upon the various aspects of water circulation, including: (i) managing flood risks through reducing stormwater runoff, (ii) enhancing groundwater recharge, and (iii) reducing drought risks through water storage. Stormwater runoff management measures included 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.

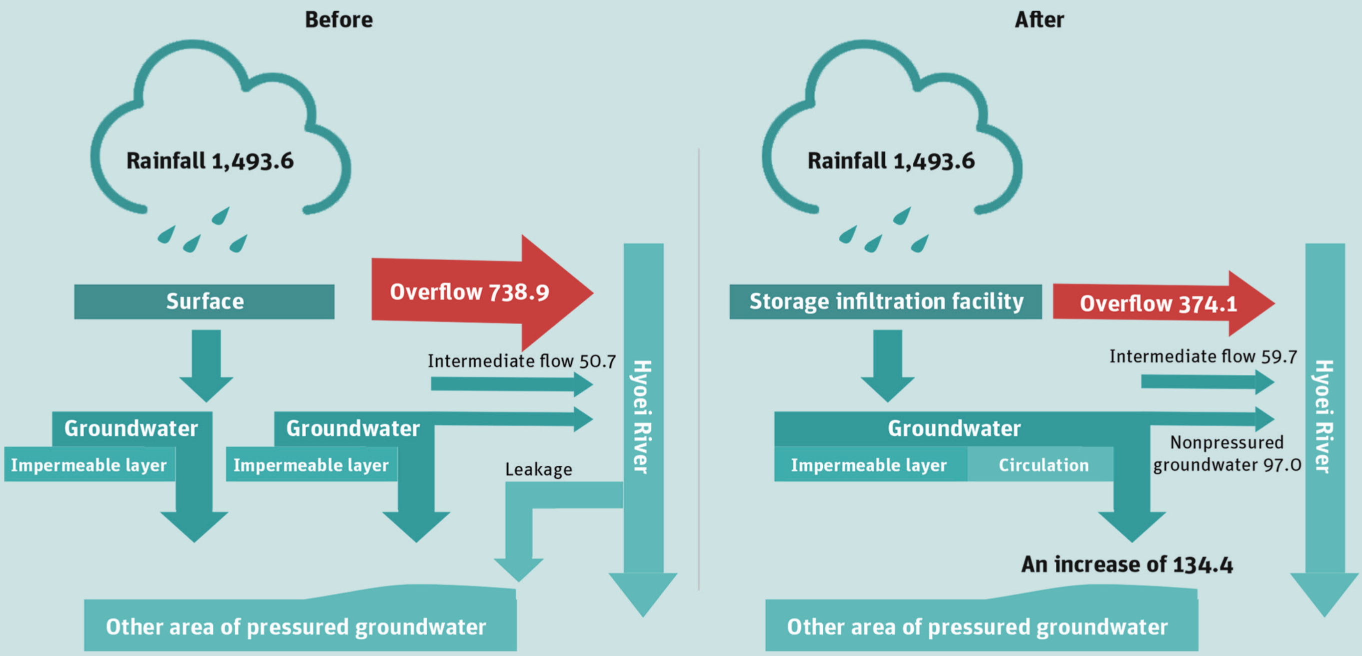
Figure B1.3: Monitoring and Evaluation Area at Hachioji Minamino City





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

<table>
<tr><th>Enabling Factors for O&M</th><th colspan="4">Description</th></tr>
<tr><td rowspan="4">Policy and institutional frameworks 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</td><td colspan="4">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, figure 6 provides and example from the implementation of the Futako-tamagawa Rise and Futakotamagawa Park Project, where O&M responsibilities were shared between the government, private developers, tenants, and community mem-bers, through a combination of policy incentives and collaboration.</td></tr>
<tr><th colspan="4">Tools and Approaches</th></tr>
<tr><th>Guidelines and Manuals</th><th>Monitoring and Management Plans</th><th>Engagement of Various Stakeholders</th><th>Innovative Technologies</th></tr>
<tr><td>Describe and elaborate</td><td></td><td>Require</td><td></td></tr>
<tr><td rowspan="3">Human resources include appropriate knowledge and skills to implement O&M plans and procedures</td><td colspan="4">The engagement of various stakeholders, together with asset owners and managers, could enhance the effectiveness and sustainability of O&M as well as flood manage-ment investments. Capacity building, training, and clear guidance on O&M procedures is needed for securing diversified human resources for O&M.</td></tr>
<tr><th>Guidelines and Manuals</th><th>Monitoring and Management Plans</th><th>Engagement of Various Stakeholders</th><th>Innovative Technologies</th></tr>
<tr><td></td><td>Ensure and monitor</td><td></td><td>Support and require</td></tr>
<tr><td rowspan="3">Investment design takes into consid-eration requirements and ease of O&M</td><td colspan="4">Considering the frequency, types, and resources needed for repair, replacement, and reconstruction while selecting the investment design is important. Therefore, explor-ing 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.</td></tr>
<tr><th>Guidelines and Manuals</th><th>Monitoring and Management Plans</th><th>Engagement of Various Stakeholders</th><th>Innovative Technologies</th></tr>
<tr><td>Inform</td><td></td><td></td><td>Enable</td></tr>
</table>

<table>
<tr><th>Enabling Factors for O&M</th><th colspan="4">Description</th></tr>
<tr><td rowspan="4">Financial resources are available to cost-effectively carry out necessary O&M activities throughout the life cycle of the investment</td><td colspan="4">Securing financial resources and reducing the costs of O&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.
Box 2 provides an example from Tokyo of the financial resources mobilized for the O&M of sewerage facilities in the Tokyo Metropolitan Government area, which serves a critical role in managing urban floods in dense urban spaces.
In section 4, specific examples of cost-sharing arrangements between the public sector, private sector, as well as citizens and communities are provided.</td></tr>
<tr><td colspan="4">Tools and Approaches</td></tr>
<tr><td>Guidelines and Manuals</td><td>Monitoring and Management Plans</td><td>Engagement of Various Stakeholders</td><td>Innovative Technologies</td></tr>
<tr><td></td><td>Ensure and monitor</td><td>Enable and increase</td><td>Enable</td></tr>
</table>

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	**River management facilities,** including: • River embankments • Underground river overflow management facilities (cisterns, channels, etc.) • Reservoirs, detention parks, and ponds	• River Erosion Control: Technical Standards for Maintenance • River Management Facilities such as Levees and Inspection Method for River Channels • Detailed Inspection Method for Embankments around Structures such as Gutters • River Management Facilities such as Levees of Medium and Small Rivers and Inspection Methods for Riverways • River Levee Qualitative Maintenance Technology Guidelines (plan), 2014 • River Levee Monitoring Technology Guidelines (plan) • Inspection and Evaluation Procedures for River Management Facilities • Levee and Revetment Inspection Results Evaluation Procedure (draft) • Sluiceway/Gutter Tube Inspection Results Evaluation Procedure: River Edition (draft)	MLIT[4]
Surface water flood	**Sewerage facility:** • Underground stormwater management facilities (cisterns, channels, drainage pipes, culverts, etc.) • Stormwater detention ponds, parks, and gardens • Sewerage treatment facility improvement	• Guidelines for Selecting PPP / PFI Methods in Sewerage Projects • Guidelines for Draft Stormwater Management Comprehensive Plan • Guidelines for Implementing Stock Management of Sewerage Projects • Handbook on Formulating Sewerage Life Extension Plan Based on Stock Management Method • Comprehensive Private Consignment Introduction Guidelines for Sewerage Pipeline Facility Management Work • Maintenance Management of Sewage Sludge Treatment in Tokyo Metropolitan Government • Sewerage Pipeline Facility Maintenance Manual	• MLIT[5] • MLIT[6] • MLIT[7] • MLIT[8] • MLIT[9] • Private company[10] • Public Interest Incorporated Association[11]
	Stormwater storage and infiltration facilities, including: • Rainwater harvesting systems (collection systems and storage tanks installed in public, commercial, community buildings) • Enhancement of infiltration surface (green spaces, pervious pavers and infiltration trenches, etc.)	• Guidance on Promoting Development of Stormwater Infiltration Facilities (draft) • Technical Guidelines for Stormwater Storage and Infiltration Facilities of Tokyo Metropolitan Government • Technical Guidelines for the Installation of Temporary Storage Facilities, etc. in Public Facilities of Tokyo Metropolitan Government • Technical Guidelines for Stormwater Infiltration Facilities, Structure, Construction, and Maintenance Management (draft) • River Storage Facilities etc. Technical Guidelines (draft) • Manual on Stormwater Retention and Infiltration Facilities Installation in Detached Houses	• MLIT[12] • TMG and local municipalities[13] • TMG, Bureau of Urban Development[14] • Public Interest Incorporated Association[15]
Storm surge flood	**Coastal Protection Facilities**: • Embankments, revetments, parapet walls, etc.	• Coastal Protection Facility Maintenance and Management Manual: Inspection, Evaluation and Long-life Planning for Embankment, Revetment, and Parapet Walls, 2014	• MLIT and MAFF (Ministry of Agriculture, Forestry and Fisheries)[16]

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.

4 For more details, see http://www.mlit.go.jp/river/kasen/main/maintenance/index.html.
5 For more details, see http://www.mlit.go.jp/common/001170811.pdf.
6 For more details, see http://www.mlit.go.jp/mizukokudo/sewerage/mizukokudo_sewerage_tk_000433.html.
7 For more details, see http://www.mlit.go.jp/river/suibou/pdf/gesui_stockmanagement_guideline2015.pdf.
8 For more details, see http://www.mlit.go.jp/common/001012691.pdf.
9 For more details, see https://www.mlit.go.jp/common/001043219.pdf.
10 For more details, see http://www.tgs-sw.co.jp/business/service/c01/c01/#t01.
11 For more details, see https://www.jascoma.com/doc/book/list/gijutu-h1905.html.
12 For more details, see http://www.mlit.go.jp/common/000113727.pdf.
13 For more details, see http://www.tokyo-sougou-chisui.jp/shishin/shishin.pdf.
14 For more details, see http://www.tokyo-sougou-chisui.jp/shishin/GijutuShishin.pdf.
15 For more details, see https://arsit.or.jp/book14, https://arsit.or.jp/book13 and http://arsit.or.jp/wp/img/book/kodate.pdf.
16 For more details, see http://www.maff.go.jp/j/nousin/bousai/kaigan/ijikanri_manual_iinkai/pdf/manual_main-1.pdf.

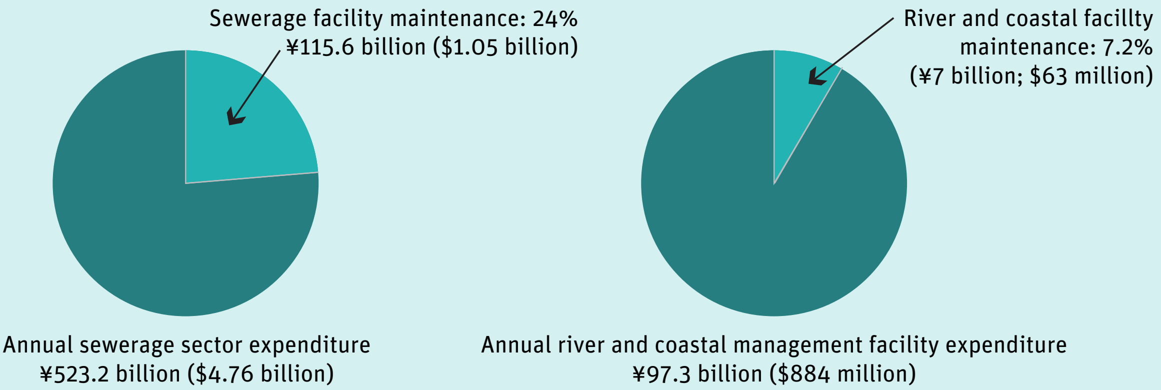
Sharing O&M Costs and Responsibilities with the Public Sector

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[17] 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.

17 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

<table>
<tr><th>Scope of Work</th><th>Direct Governance / Individual Outsourcing</th><th>Private Subcontracting</th><th>Design, Build, and Operate</th><th>Conventional PFI Method</th><th>Concession</th></tr>
<tr><td>Top-down execution</td><td rowspan="9">Municipality</td><td rowspan="6">Municipality</td><td rowspan="5">Municipality</td><td rowspan="4">Municipality</td><td rowspan="2">Municipality</td></tr>
<tr><td>Decision making and consensus building</td></tr>
<tr><td>Establishment of plan</td><td rowspan="7">Private Sector</td></tr>
<tr><td>Collection of fee from the public</td></tr>
<tr><td>Securing financial source</td><td rowspan="5">Private Sector</td></tr>
<tr><td>Facility (design and construction)</td><td rowspan="4">Private Sector</td></tr>
<tr><td>Facility repair and renew</td><td rowspan="3">Private Sector</td></tr>
<tr><td>Inspection and maintenance</td></tr>
<tr><td>Operation</td></tr>
<tr><td>Remarks</td><td>Implementing directly by the municipalities or subcontracting required services to the private sector.</td><td>Subcontracting services based on tenderer's performance and capability, with more than one-year contract.</td><td>Subcontracting design, building, and O&M as a package (financial source to be secured by the public sector).</td><td>Subcontracting design, building, and O&M as a package (financial source to be secured by the private sector).</td><td>Subcontracting the management right. Private sector to collect service fee from the public.</td></tr>
<tr><td>Typical contract period</td><td>1 year</td><td>3–5 years</td><td>15–20 years</td><td>Approximately 20 years</td><td>Approximately 20 years</td></tr>
<tr><td>Number of completed projects as of January 2018</td><td>-</td><td>450</td><td>25 (including ongoing cases)</td><td>11</td><td>1</td></tr>
<tr><td>Implemented cases</td><td>-</td><td>Kahoku City etc.
Treatment plant and sewerage pipe's O&M</td><td>TMG etc.
Project on recycling sewerage sludge</td><td>Yokohama City
Project on recycling sewerage sludge</td><td>Hamamatsu City
Treatment plant and pumping station's O&M and renovation</td></tr>
</table>

Source: MLIT n.d.(d).

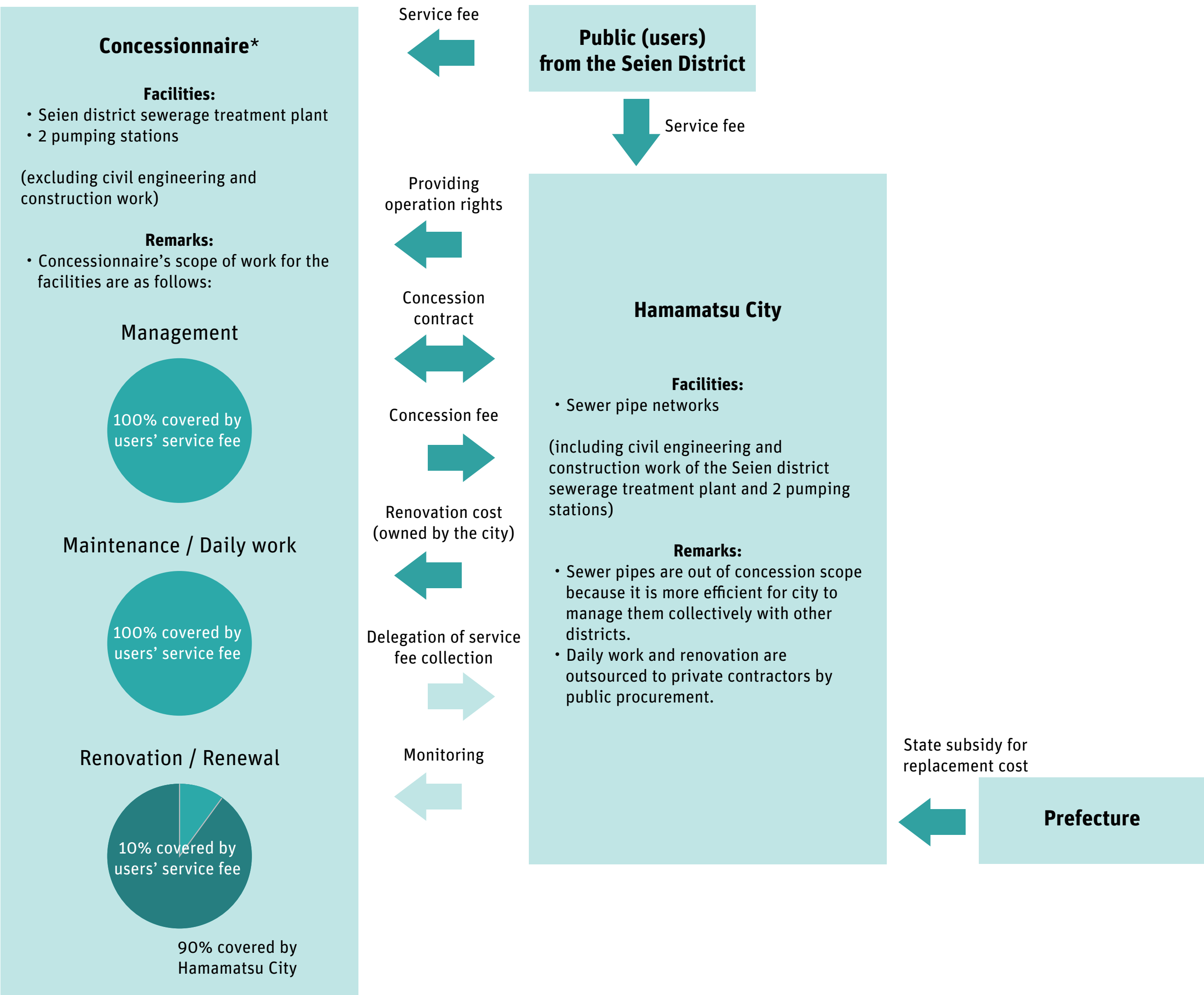
Note: O&M = operation and maintenance; PFI = private financed initiative; TMG = Tokyo Metropolitan Government.

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

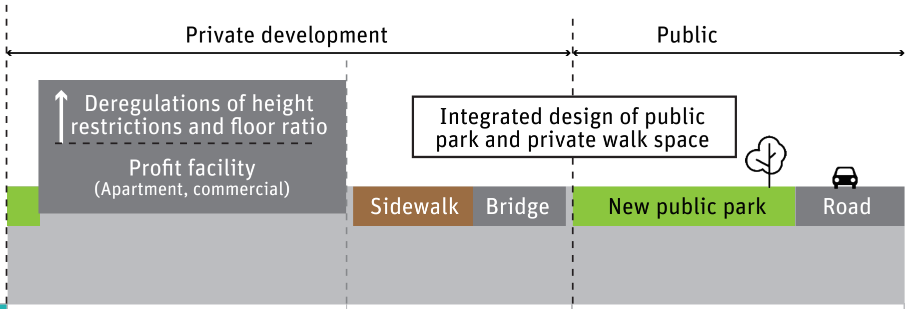


* Hamamatsu Water Symphony Co., Ltd.
established by six companies, including Veolia Japan.

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



	Private development		Public
Government: MLIT, TMG, and Setagaya Ward	Deregulation	Partially subsidizing O&M activities	Lead construction and O&M
Private developers and landowners: the members of the redevelopment association	Lead construction and O&M		Coordination
Tenants and community members	—	Participation in O&M activities	—

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^3 and a reuse storage capacity of 800 m^3. 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[18] 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

18 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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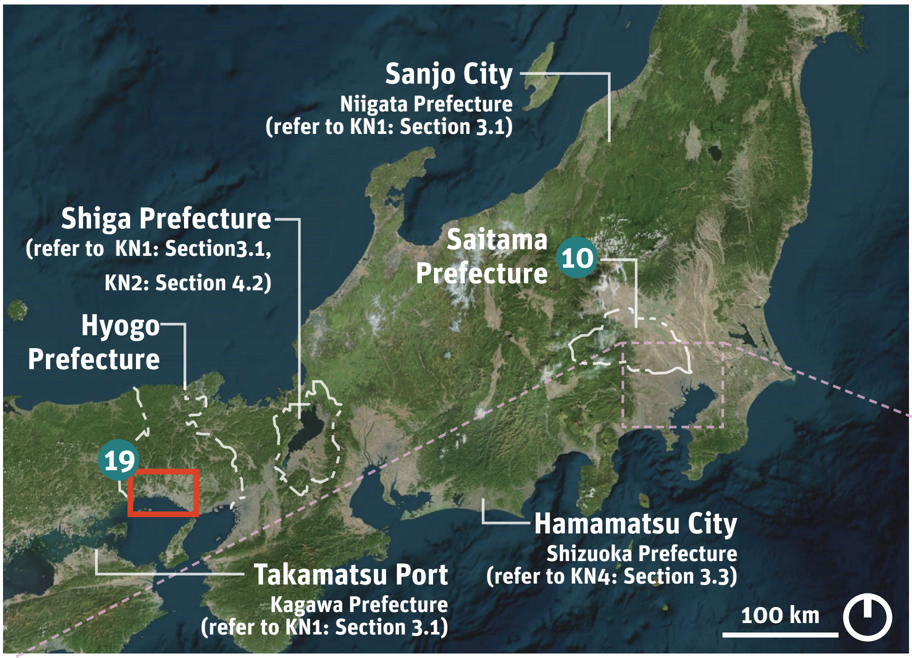
Appendix:
Case Studies in Integrated Urban Flood Risk Management in Japan

This appendix provides a collection of case studies of flood risk management initiatives in Japan introduced within the series of Knowledge Notes on Japan's Experience in Integrated Urban Flood Risk Management, particularly Knowledge Notes 3 and 4. The project costs of each case included in the appendix are converted into U.S. dollars ($) at the 2018 annual average exchange rate of $1 = ¥110, based on the yearly average currency exchange rate provided at https://www.irs.gov/individuals/international-taxpayers/yearly-averagecurrency-exchange-rates.

Cover Image: A view of the Hachioji Minamino District in Hachioji City, Tokyo.
A new town development incorporated environmental conservation and flood mitigation measures along the Hyoei River.

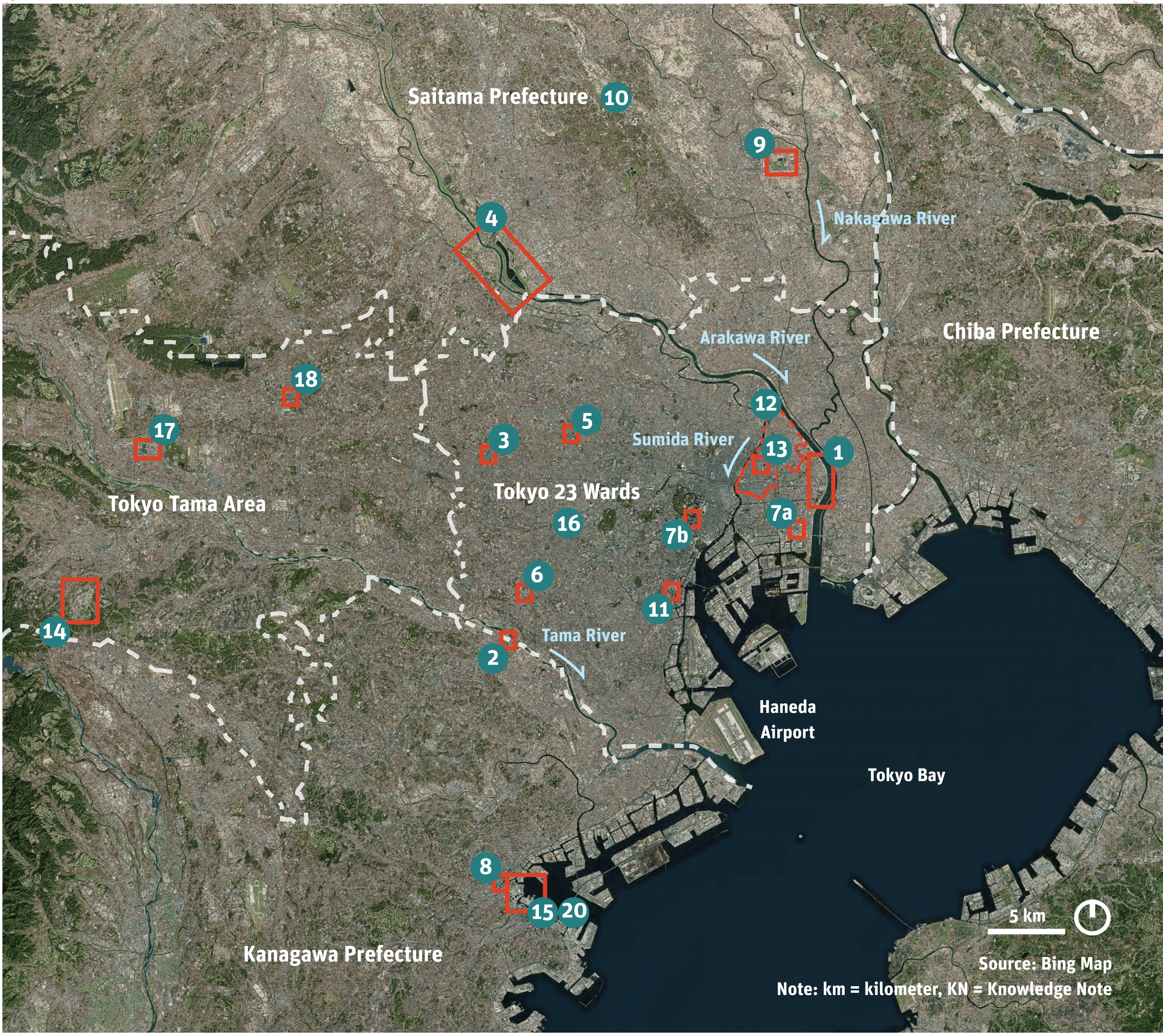
(Photo Credit: Kenya Endo)



Flood type
- River flood
- Surface water flood
- Storm surge flood

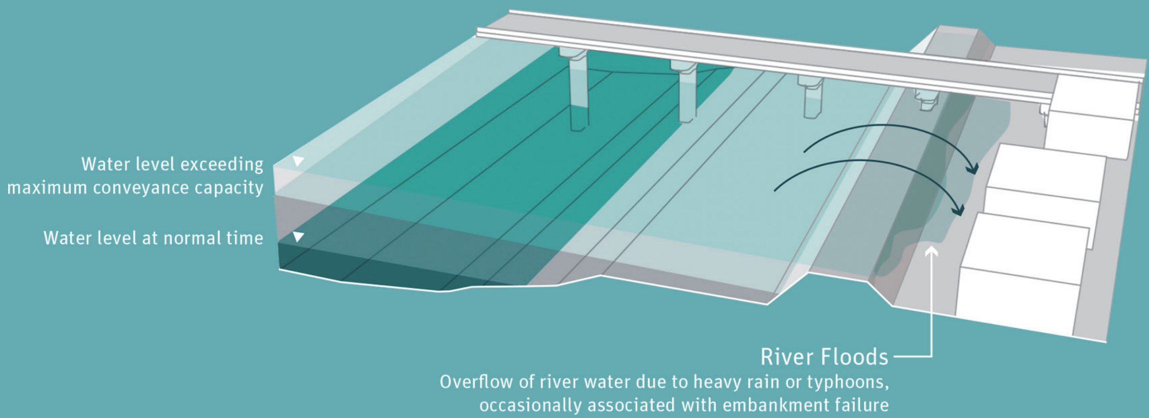
Type of measure
- Structural (gray)
- Structural (green)
- Nonstructural (policy)
- Nonstructural (innovative methodologies)

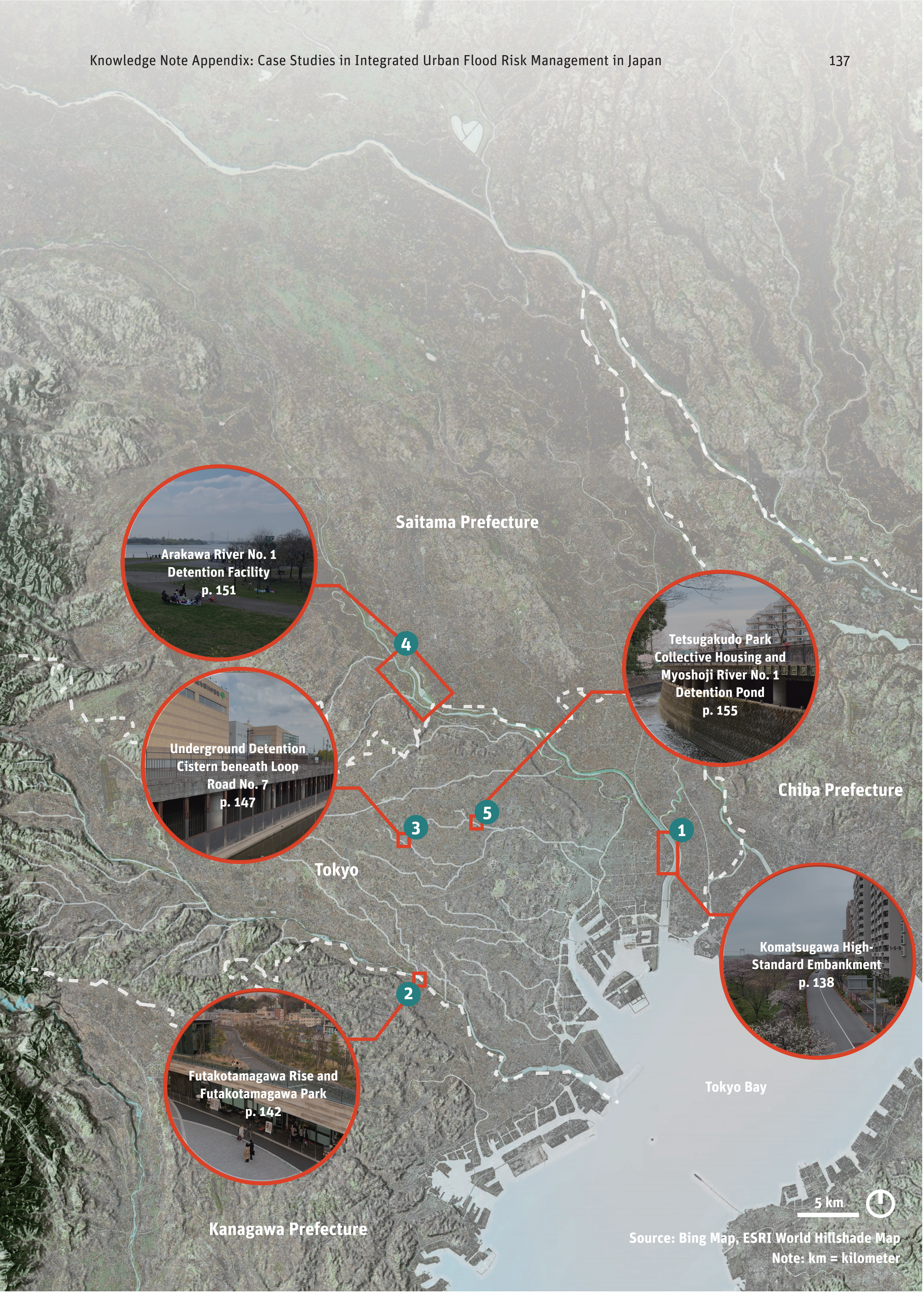
O&M learning points included (refer to **KN4**)



List of Cases

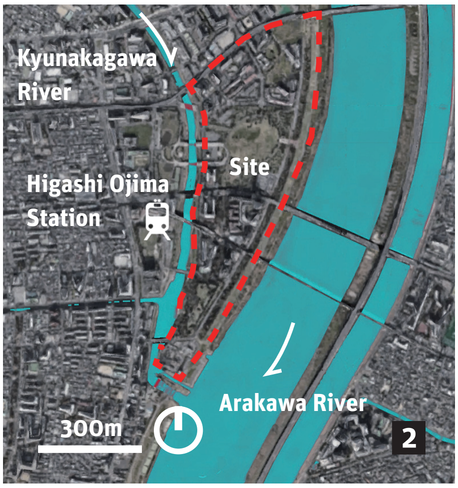
River Floods




Saitama Prefecture
Arakawa River No. 1
Detention Facility
p. 151
4
Tetsugakudo Park
Collective Housing and
Myoshoji River No. 1
Detention Pond
p. 155
Underground Detention
Cistern beneath Loop
Road No. 7
p. 147
3
5
1
Chiba Prefecture
Tokyo
Komatsugawa High-
Standard Embankment
p. 138
2
Futakotamagawa Rise and
Futakotamagawa Park
p. 142
Tokyo Bay
5 km
Kanagawa Prefecture
Source: Bing Map, ESRI World Hillshade Map
Note: km = kilometer

Case 1: Reducing River Flood Risk and Promoting Urban Redevelopment: Komatsugawa High-Standard Embankment

Location:	Komatsugawa District, Edogawa Ward, Tokyo
Site characteristics:	Dense urban area with high concentration of assets and population in the surrounding area
Flood management measure(s):	
Flood type	River
Management capacity	Accommodate a maximum 1-in-200-year storm event
Type of measure(s)	Structural (gray): improvement of embankment
Relevant entities:	
Implementation	Embankment—national government (river administrator)
	Urban redevelopment zones—Tokyo Metropolitan Government (TMG)/Edogawa Ward and Urban Renaissance Agency (UR)[a]
Operation and maintenance (O&M)	Same as above
Finance	Same as above
Construction period:	1990–2015
Cost:	Construction cost: ¥48.8 billion ($444 million, as of 2011)[b]
Additional benefits and functions:	Urban redevelopment (residential, commercial, and industrial)
	Disaster risk management (provision of emergency evacuation sites during floods and earthquakes)[c]
Source:	MLIT, n.d.(a), except where otherwise noted.
	a For more information, see www.toshiseibi.metro.tokyo.jp/bosai/sai_kai-kameido.pdf.
	b MLIT 2011.
	c Edogawa Ward 2006.

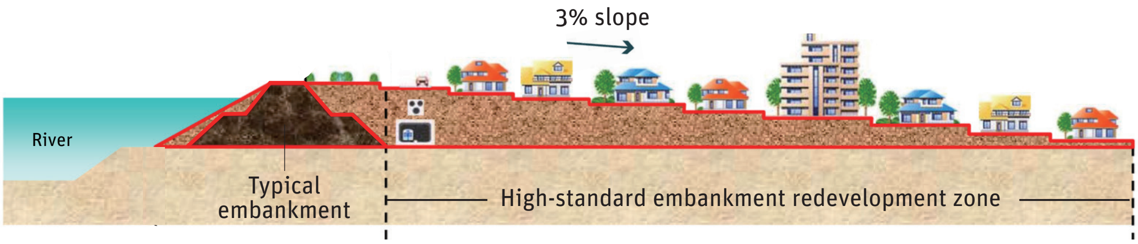


Context: Flood Risk and Significance of Area

Komatsugawa District is in **Edogawa Ward**, located in eastern Tokyo in the Koto Delta along the Arakawa River. The district's proximity to a large river, Arakawa, and its location below sea level exposes it to significant inundation risk. Its low elevation also means that, before the intervention, safe evacuation ground was not available for area residents in the event of floods. A flood impact analysis conducted in 2011 showed that if the Arakawa River were to overflow, the economic impact in Komatsugawa District could be up to ¥71 billion (US$645 million).[1]

In 1990, Edogawa Ward, in partnership with the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), initiated a project with the dual objectives of

1 For more information, see MLIT, Kanto Regional Office (2011).



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reducing losses and damage to people and assets from flooding and establishing a safe site for evacuation during floods. A high concentration of population and assets in the surrounding areas, which are utilized for industrial, commercial, and residential purposes (Hashiguti, Hirabayashi, and Yamazaki 2009), strongly necessitated the implementation of a high-standard flood protection investment. Therefore, despite the high cost, lengthy construction time, and complicated relocation processes involved, the national and local governments together embarked on a project to establish a high-standard embankment with a design that aims to withstand a 1-in-200-year flood. This “super-levee” infrastructure was selected as the flood management approach in Komatsugawa District, as well as for other high-density and high-priority areas in the Tokyo Metropolitan Area facing similar flood risks and potential impacts.

Given its greater width and height as compared to traditional embankments, the design and construction of the super-levee was implemented jointly with an overall urban redevelopment project of Komatsugawa District.

Solution: Investment Design and Key Features

Investment Design

The high-standard embankment in Komatsugawa District is 2,380 meters (m) long, with a mean width of 97 m and an area of 23.3 hectares (ha) (MLIT n.d.[a]; Nakamura, Kato, and Shiozaki 2013). In addition to its utility for managing river flooding with up to 200-year return periods, it is used as a residential area, a public park that also serves as a disaster evacuation site, and a site for public facilities (a junior high school and a pumping station). Construction started in 1990 and was completed after 25 years in 2015. The total construction cost was an estimated ¥48.8 billion ($444 million). The many housing relocations and significant land compensation involved were some of the key challenges and reasons for the high cost and the long time required to build it.

As illustrated in **figure A1.3**, unlike a typical embankment, a high-standard embankment’s sectional profile requires a large area for construction at the back side of the river to ensure structural stability. Komatsugawa’s high-standard embankment project also included approximately 97 ha of urban redevelopment area, utilized for housing, commercial, and industrial purposes (MLIT n.d.[a]; **figure A1.6**).

Key Features

- **Coordination and partnership among the national government, local government, and developers:** To carry out the large-scale, high-cost, and complex flood management project in Komatsugawa District, sharing of the responsibilities, costs, and risks of the project among various stakeholders was vital, as was ensuring their close coordination throughout the long period of project implementation. The national government (MLIT, which serves as the river administrator), the Tokyo Metropolitan Government (TMG)[2] and the local government (Edogawa Ward), and the housing developer (the Edogawa Ward and Urban Renaissance Agency, or UR)[3] jointly carried out the embankment design, construction, and urban redevelopment work. TMG, supported by the river administrator and UR, carried out the complex and time-consuming land readjustment work, the rezoning, and the establishment

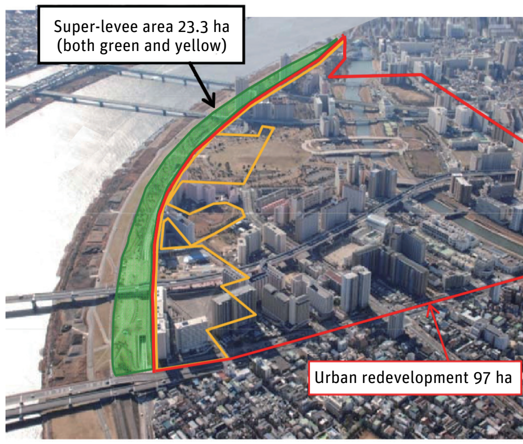

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Figure A1.1: Overall View of the Site

Photo Credit: Kenya Endo.

Figure A1.2: Site Context

Source: Google Earth. Note: m = meter.

Figure A1.3: Conceptual Diagram of the High-Standard Embankment

Source: MLIT, Kanto Regional Office 2011.

Figure A1.4: Komatsugawa District before Development

Source: MLIT n.d.(a) (above); MLIT n.d.(b) (below).

Figure A1.5: Komatsugawa District after Development and Zoning

Source: MLIT n.d.(a). Note: ha = hectare.

Figure A1.6: Redeveloped Neighborhood Cityscape

Photo Credit: Kenya Endo.

of public facilities. Edogawa Ward led a process of building consensus among residents and promoting awareness of the necessity for a high-standard embankment in the region, which led to the residents' agreeing to temporary or permanent relocation.

- **Design of a multipurpose and multibenefit investment:** The high-standard embankment in Komatsugawa District was designed to serve three purposes: (i) to provide river flood protection; (ii) to provide a disaster evacuation site; and (iii) to provide attractive residential and commercial spaces with access to public amenities. Various planning and design innovations have enabled the single-investment project to generate multiple benefits. Based on the "Structure Decree on River Facility Management and Manual for River Works," established by the national government, the slope of the inner side of the embankment, for example, had to be within 3 percent so it would not be broken by excessive flooding. Furthermore, the structure of the embankment had to be resistant to earthquakes and available for residential development. The embankment's strong structure also allows it to function as an evacuation site.
- **Cost sharing and cost reduction measures among various stakeholders:** Given the involvement of the various stakeholders, different components of the Komatsugawa Embankment and redevelopment project were financed by different actors. In general, the embankment was financed by the river administrator and TMG's river development authorities. The urban redevelopment initiatives were financed mainly by TMG's Urban Development Department and UR. Costs for community consultations, consensus building, compensation (that is, partial compensation for temporary relocation, demolition and reconstruction of housing units, and so on), and tax incentives (such as reduction of the homeowner tax) were mainly covered by TMG. To lower the overall project cost, the river administrator decided to retain ownership of the site, essentially by not acquiring any land for the high-standard embankment. In other words, former residents were able to move back to the same location after rezoning and construction work were completed. Urban redevelopment of the site was effectively planned by TMG and initiated by the private sector with enhanced urban amenities, with some evidence of the land value increasing after the project.[4]
- **Remaining challenges:** The high cost, lengthy duration, and need for relocation over a large area remain key challenges in implementing a large-

2 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.).

3 UR is a semipublic independent administrative institution and an agency responsible for Japanese housing.

4 A report by the Riverfront Research Institute (2006) found that the value of land in Komatsugawa District protected by the embankment increased at a higher rate (from ¥227,000/square meters [m^2] in 1996 to ¥304,000/m^2 in 2004, a 34 percent increase) than land in areas outside the embankment's protection (from ¥255,000/m^2 in 1996 to ¥299,000/m^2 in 2004, a 17 percent increase).

scale river embankment project. How to provide incentives strategically to the private sector to partner in such long-term initiatives remains a key challenge to further expanding and scaling up these initiatives. Building the slope of the inner side of the embankment, for example, requires large earthworks, as well as the simultaneous raising up of all utility and service infrastructure. This work can take up to two or three years for completion, and extended time for embankment construction will discourage the private sector's involvement in subsequent urban redevelopment (Hashiguti, Hirabayashi, and Yamazaki 2009).

Results: Multiple Benefits

The high-standard embankment project improved the disaster risk management capacity of the flood-prone Komatsugawa District and its surrounding area in the Koto Delta through the establishment of a structurally sound foundation able to withstand up to 1-in-200-year river floods. The embankment also created a new ward-wide evacuation hub in case of floods and other natural disasters (**figure A1.7**). Implemented jointly with a large-scale urban redevelopment project led by a housing development agency, the historically dense, disaster-prone neighborhood was transformed into an attractive living environment with improved safety and scenic views toward the Arakawa River, increasing property values in the area.

Figure A1.7: Evacuation Drills at Komatsugawa High-Standard Embankment
Source: MLIT, n.d.(b).

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1

Case 2: Reducing River and Surface Water Flood Risk by Integrating Nature-Based Solutions within an Urban Redevelopment Project: Futakotamagawa Rise and Futakotamagawa Park

Location:	Futakotamagawa District is located in Setagaya Ward, Tokyo, approximately 15 kilometers (km) southeast of Tokyo's city center and adjacent to the large Tama River.
Site characteristics:	The area is mainly dense residential, but commercial buildings and offices are located near Futakotamagawa Station. It is prone to high flood risk due to its proximity to the Tama River, as well as urbanization and limited infiltration capacity.
Flood management measure(s):	
Flood type	River and surface water
Management capacity	Futakotamagawa Rise, including Futakotamagawa Park: River flooding: High-standard embankment designed to manage 1-in-100-year or 1-in-200-year flood events
	Surface water flooding: Detention—approximately 5,500 cubic meters (m^3) total (4,400 m^3 underground rainwater detention facility and 1,110 m^3 stormwater detention pond)[a]; infiltration—approximately 670 m^3 (through permeable pavers and infiltration trenches, etc.); greenery (natural infiltration)—approximately 1,300 m^3
Type of measure(s)	Futakotamagawa Rise: Structural rainwater harvesting and stormwater management measures (gray and green)
	Futakotamagawa Park: Structural rainwater harvesting and stormwater management measures (green) and high-standard embankment (gray)
Relevant entities:	
Implementation	Futakotamagawa Rise (11.2 hectares [ha]): Futakotamagawa East District Urban Redevelopment Association led by Tokyu Land Corporation and Tokyu Corporation in collaboration with TMG/Setagaya Ward
	Futakotamagawa Park (6.3 ha): Setagaya Ward in partnership with Tokyu Land Corporation and Tokyu Corporation, TMG, and MLIT (1,250 m of high-standard embankment)[b]
O&M	Futakotamagawa Rise: Tokyu Corporation
	Futakotamagawa Park: Setagaya Ward with residents
Finance	Futakotamagawa Rise: Tokyu Corporation with subsidies from TMG/Setagaya Ward
	Futakotamagawa Park: Park—TMG/Setagaya Ward; embankment—MLIT and TMG/Setagaya Ward
Construction period:	2007–15[b]
Cost:	Futakotamagawa Rise: Total cost of Futakotamagawa East Urban Redevelopment Project Phase 1 (8.1 ha out of 11.2 ha)—¥102.4 billion ($875 million)[b]
	Futakotamagawa Park: Park total—¥1.274 billion ($11.6 million), of which ¥40 million ($364,000) is for flood management measures[b]; embankment—unknown[c]

Additional benefits and functions:	Urban redevelopment: Housing and commercial development
	LEED ND (neighborhood development) Gold Certified
	Disaster risk management: Evacuation site, backup power generator, solar- and wind-powered streetlights, backup water source, emergency toilets, disaster preparedness equipment storage
	Environmental sustainability: Enhancement of biodiversity and mitigating of heat island effect; water recycling
Sources:	Nikkan Kogyo Shimbun 2017, except where otherwise noted.
	a Setagaya Ward 2013.
	b Bureau of Urban Development, TMG 2015.
	c The total national project cost for the high-performance embankment, 1987–2010, was reported as ¥693.6 billion, or $6.3 billion (Board of Audit of Japan 2012).

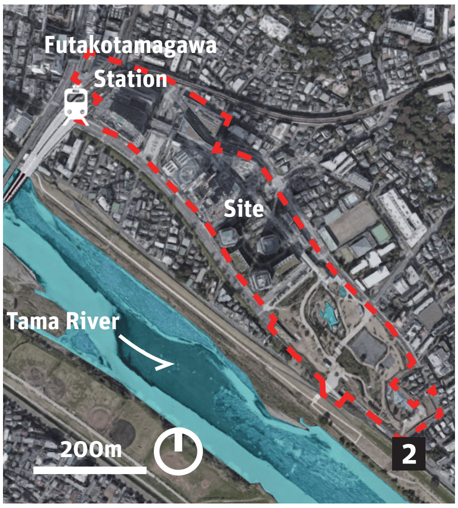

Figure A2.1: Overall View of the Site

Photo Credit: Kenya Endo.

Figure A2.2: Site Context

Source: Google Earth. *Note*: m = meter.

Context: Urban Redevelopment and Flood Risks

A gateway to western Tokyo, the upscale **Futakotamagawa** area is bounded by the Tama River and the Kokubunji cliff line. An expansion of residential neighborhoods there coincided with the growth of a commercial district surrounding Futakotamagawa Station, with major department stores opening in 1969. In the mid-1980s, however, vacancies in shopping arcades led to an economic decline on the east side of Futakotamagawa Station, resulting in underutilization of this high-value land with good access to the urban centers of Tokyo (MLIT, Kanto Regional Office 2001).

Furthermore, given its proximity to the Tama River, flood risk was also a concern in advancing further development in the area. During Typhoon Fitow (No. 9) in 2007, **Setagaya Ward** issued an evacuation advisory to 1,490 people and 740 households in the area, while MLIT and the ward stacked sandbags by the river, which prevented major inundations. With increasing risks of heavy rain and extreme weather events, there was a growing need for more robust flood management measures in the area (MLIT, Kanto Regional Office, n.d.).

Solution: Investment Design and Key Features

Investment Design

In light of this situation, in 2005, TMG approved the implementation of the 11.2 ha Futakotamagawa East District Category One Urban Redevelopment Project. Tokyu Corporation formed a redevelopment committee called the Futakotamagawa East District Urban Redevelopment Association (F-Inc. n.d.) to lead the implementation in two major phases, starting in 2007. Simultaneously, in conjunction and close coordination with this project, Setagaya Ward led the redevelopment of the connecting 6.3 ha area as the Futakotamagawa Park, which would also serve as a high-standard embankment against river flooding (**figure A2.3**).

The Futakotamagawa Rise project's key concept was "Water, Greenery, and Light," emphasizing the harmonization of nature and green features throughout the design of its office buildings, commercial facilities, hotels, and residential developments. Construction of the buildings and infrastructure of the project applied environmentally friendly methods, such as the installation of green roofs, solar panels, geothermal heat exchangers, and the use of recycled materials. Additionally, rainwater harvesting and recycling systems, as well as stormwater detention facilities, were integrated into the main building, and a number of eco-ponds and planting beds were installed (**figure A2.4**). The combination of urban

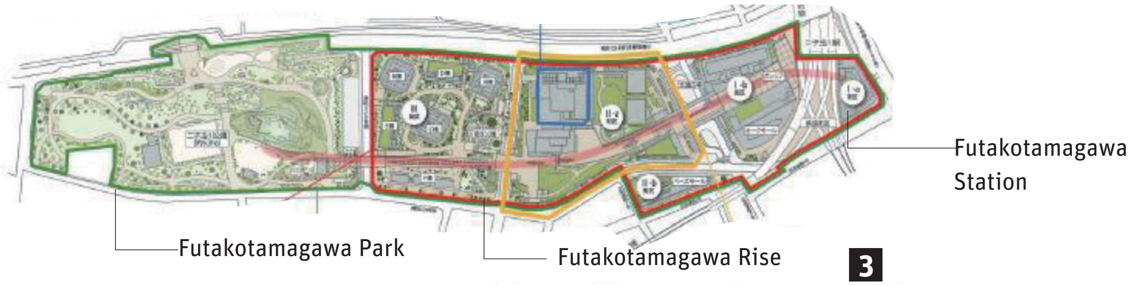

Figure A2.3: Overall Site Zoning

Source: Futakotamagawa Rise n.d.

Figure A2.4: Futakotamagawa Rise Retail Businesses and Roof Garden

Photo Credit: Kenya Endo.

redevelopment with flood risk mitigation presented some challenges, including the need for private investment, the regulatory burden, and the cost burden on redevelopment companies. The need for consensus among stakeholders and for sustainable operation and maintenance (O&M) after the redevelopment were also significant challenges.

The Futakotamagawa Park was developed as a public park by Setagaya Ward on a raised high-standard river flood embankment developed by MLIT (Board of Audit of Japan 2012). The park also has an underground rainwater detention pond, permeable pavers, and an infiltration trench, as well as a green space to manage stormwater overflow (**figures A2.5 and A2.6**).

Key Features

- **Integration of nature-based solutions:** The Futakotamagawa Rise project was awarded the world's first Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND) gold certificate, based on its integration of various energy, environmental, and flood management benefits through both structural solutions, including gray and green solutions, and nonstructural solutions, including strong participation in the design, implementation, and O&M of the project.[5] The collective approach and seamless integration of both private and public development in one cohesive development project rather than individual smaller ones enabled the attainment of economic, environmental, and disaster risk management benefits, with less technical and financial burden, through role sharing among the various stakeholders.
- **Mechanisms for coordination and collaboration in multipurpose and multibenefit investments:** Various mechanisms were put into place to enable the different stakeholders to collaborate through a coordinated approach. To make it easier for the private developers—the Tokyu Land Corporation and Tokyu Corporation—to apply progressive disaster-resilient and environmentally sustainable construction methods and infrastructure design, Setagaya Ward and TMG relaxed their regulations on floor area ratio (FAR) and height limits on the proposed high-rise commercial, residential, and office buildings. Extensive consultation with the local residents by the Redevelopment Association, Setagaya Ward, and MLIT made possible the development of the high-standard embankment and the park. The public and private sectors, for example, spent several years in discussion with local residents to build consensus, and, as a result of this extensive dialogue, about 200 landowners joined the Redevelopment Association and offered their land for the redevelopment project under consensual terms. The active collaboration and engagement of the community continues to date, with various programs related to public awareness, environmental education,

5 LEED (Leadership in Energy & Environmental Design) is a green building certification system administered by the U.S. Green Building Council (USGBC). Among LEED certificates, LEED-ND (Urban Development) is awarded for environmental consideration, energy resource efficiency, and pedestrian-centered development. LEED-NC (New Buildings) is for environmental evaluation of new buildings, as well. For more information, see https://new.usgbc.org/.

green infrastructure, and flood risk management taking place regularly, with partial support from TMG and Setagaya Ward's community development and environmental subsidy programs (Bureau of Urban Development, TMG 2018).

- **Private and community participation in O&M:** Given the diverse stakeholders involved in the development and implementation of the Futakotamagawa Rise and Futakotamagawa Park development projects, the stakeholders were also able to share responsibility for O&M. As illustrated in **figure A2.7**, O&M, including for the flood management facilities within the Futakotamagawa Rise development, is shared among Tokyu Corporation, the developers, tenants, and citizens—for example, through the establishment of community-based environmental education groups. O&M for the Fukatotamagawa Park is led by Setagaya Ward. Additionally, the Futakotamagawa East District Urban Redevelopment Association is active in the O&M phase, organizing a number of town management activities that include O&M for structural measures, such as rainwater storage facilities, and nonstructural measures, to enhance livability.

Results: Establishment of Multipurpose Green and Resilient Commercial, Office, and Residential Development through Multi-stakeholder Collaboration

The **Futakotamagawa** Rise and Park development project illustrates how the private sector can be engaged in integrating flood risk management investments within redevelopment initiatives through a nature-based approach, which is still rare on a larger scale in Japan. Through partnership and close coordination in public sector priorities, such as urban redevelopment, environmental conservation, and river and surface flood management, the Futakotamagawa Rise example demonstrates that through joint planning and discussion, a comprehensive, cohesive, and creative approach to combining various public and private initiatives in close consultation with residents can result in a large-scale project with substantial economic, social, and environmental benefits, together with achieving flood management goals. The Futakotamagawa Rise project has been successful in terms of demonstrating that residents of Tokyo demand and value disaster-resilient and nature-based urban development. It was able, for example, to attract Rakuten, the largest e-commerce site in Japan and among the world's largest by sales, to locate its new global headquarters in Futakotamagawa Rise. This brought 10,000 new workers to the area.

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Figure A2.5: Futakotamagawa Park and Tama River and Landscape

Photo Credit: Kenya Endo.

Figure A2.6: Installation of Underground Rainwater Detention Pond beneath Futakotamagawa Park

Source: Nikkan Kogyo Shimbun 2017.

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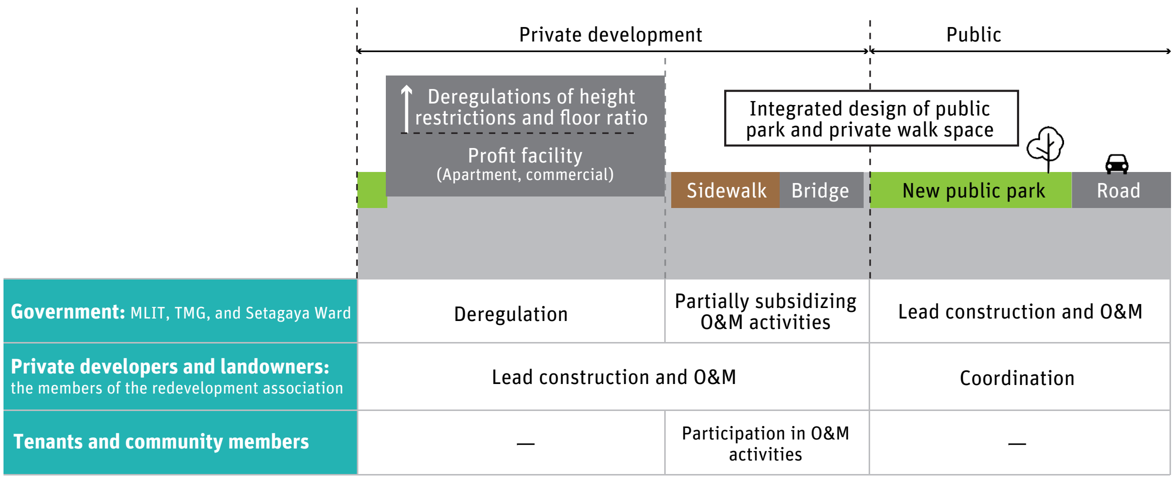


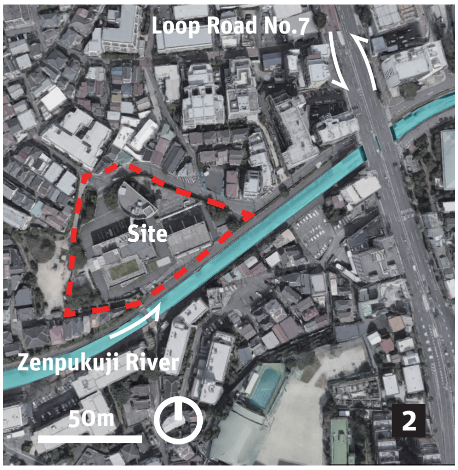
Figure A2.7: Cost Breakdown

Source: Development Bank of Japan 2019.

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

Case 3: Reducing River Flood Risk by Installing Underground Overflow Management Facilities: **Underground Detention Cistern beneath Loop Road No. 7**

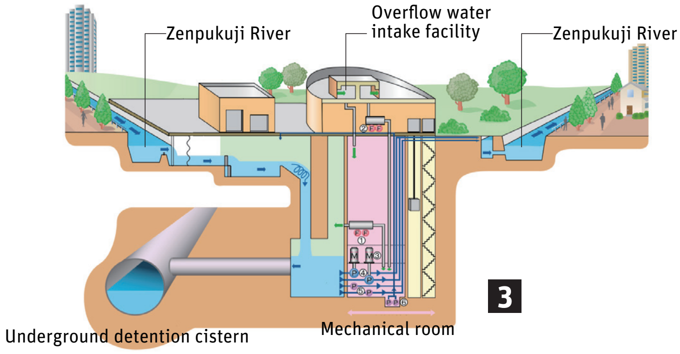
Location:	Tokyo Metropolitan Area
Site characteristics:	Dense urban area with high concentration of assets and population in the surrounding area
Flood management measure(s):	
Flood type	River and surface water
Management capacity	Designed to accommodate a maximum rainfall target of 100 millimeters (mm)/hour.
Type of measure(s)	Structural (gray)
	Underground river overflow management facility
Relevant entities:	
Implementation	Bureau of Construction, TMG
O&M	Same as above[a]
Finance	Same as above
Construction period:	1st phase of the underground detention cistern beneath Loop Road No. 7: 1988–98 (Kanda River)
	2nd phase: 1995–2008 (Zenpukuji and Myoshoji rivers)
	3rd phase: 2016–25 (scheduled, Shakujii and Shirako rivers)
Cost:	Overall construction cost: Approximately ¥103 billion ($936 million)
	Phase 1: ¥54 billion; Phase 2: ¥49 billion[b]
Additional benefits and functions:	Not applicable
Sources:	Associated General Contractors of Tokyo n.d.; Bureau of Construction, TMG 2017; Nakano Ward 2013.
	a For more information, see Bureau of Construction, TMG n.d.(a).
	b MLIT, Kanto Regional Office 2005.



Context: Flood Risk and Urbanization

During Japan's period of fast economic growth, beginning in 1955, **the western wards of Tokyo** experienced rapid urbanization. In September 1958, Typhoon Ida caused 203 deaths and flooded 460,000 buildings, wreaking the greatest flood damage of the postwar era (Bureau of Construction, TMG n.d.[b]).[6] In response to the catastrophe, in the 1960s TMG's Bureau of Construction began to implement flood protection measures for small to medium-sized rivers to cope with rainfall above 50 millimeters (mm)/hour.

6 For more information, see Bureau of Construction, TMG n.d.(c).



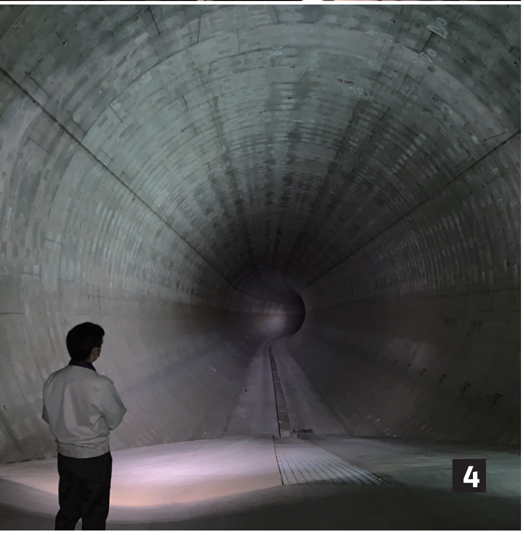


Figure A3.1: Overall View of the Site
Photo Credit: Kenya Endo.

Figure A3.2: Site Context
Source: Google Earth. *Note*: m = meter.

Figure A3.3: Conceptual Diagram of the Facility
Source: Bureau of Construction, TMG 2016.

Figure A3.4: Underground Detention Facilities
Photo Credit: Kenya Endo.

In recent years, rainfall conditions have changed and the frequency of concentrated heavy downpours has increased, with rainfalls often exceeding 50 mm/hour. According to monitoring data from TMG for the past 30 years (1978–2007), heavy rainfall over short periods occurred over 30 percent more often in central Tokyo than in the surrounding areas. In response to this finding, TMG and ward and municipal governments collected rainfall data from 117 locations, and this investigation confirmed that the northwestern part of Tokyo in particular experienced frequent heavy rains exceeding 50 mm/hour (Yokoyama 2016).

Flood protection measures carried out by TMG's Bureau of Construction aimed mainly to enlarge the conveyance capacity of waterways by widening the river's sectional profile and excavating the riverbed. These approaches were often made impossible, however, by huge land acquisition costs or the presence of public infrastructure (such as subways). The local governments could choose from two other solutions: to build a detention pond upstream of the river for temporary storage of excessive stormwater or to construct a bypass channel to reduce the flow volume at bottlenecks (Associated General Contractors of Tokyo, n.d.). Considering the growing risk of flooding near this dense urban area with highly concentrated assets and population, it was crucial for the stakeholders to take measures that could be implemented within a short construction period, with little impact to the existing infrastructure and urban setting.

Solution: Investment Design and Key Features

Investment Design

To improve safety from flood risks quickly, TMG's Bureau of Construction built an underground detention cistern 4.5 kilometers (km) in length with a diameter of 12.5 m under Loop Road No. 7, 32–40 m below ground level (**figures A3.3** and **A3.4**). This facility was designed to deal with frequent flooding at the midstream of the Kanda, Zenpukuji, and Myoshoji rivers, an area that encompasses two western wards of Tokyo (Nakano and Suginami wards). It can store up to 540,000 cubic meters (m^3) of overflow water from the three rivers (**figure A3.5**).

Key Features

- **Achievement of cost and time savings through utilizing space under public roads:** The land acquisition cost for this project was not significant because the detention cistern was built right beneath a prefectural road, Loop Road No. 7, which is public land (Associated General Contractors of Tokyo n.d.). With the road running perpendicular to the three rivers (**figure A3.6**), the construction of a linear detention cistern also saved significant cost by having a single facility deal with three watersheds.
- **Use of a phased approach to construct large-scale flood management interventions as quickly as possible:** With a risk of flooding that might result in significant damage to the surrounding neighborhoods at any moment, early completion of mitigation measures was essential. To enhance flood management capacity as quickly as possible, the project was divided into two phases. Phase 1 consisted of the completion of a 2 km cistern and an intake facility for water from the Kanda River, with an overflow management

capacity of 240,000 m^3, which started operating in 1998. Phase 2 consisted of the remaining extent, which connected with the cistern built in phase 1 and started operating in 2008 (Bureau of Construction, TMG 2016). The next phase (phase 3) will extend the water management capacity even further. The Ring Road 7 Underground Regional Detention Cistern will be completed after connecting the current extent with the Shirako River Underground Detention Cistern, which is now under construction (**figure A3.6**). Once completed, the overall length of the cistern will be 13.1 km, with an overflow management capacity of 1.43 million m^3 (Associated General Contractors of Tokyo n.d.) from five rivers (adding the Shirako and Shakujii rivers), and it will be able to cope with heavy rainfall of up to 100 mm/hour.

Results: Increased Urban Flood Risk Management Capacity in Areas with Limited Space

With Phase 1 completed, the detention cistern began to demonstrate its flood management effects when it went into operation in 1998. By the end of February 2016, stormwater had flowed into the cistern from the three rivers 38 times, effectively mitigating flood damage along them (**figure A3.7**). Typhoon No. 11 in 1993 and Typhoon Ma-on (No. 22) in October 2004, for example, produced almost the same amount of rainfall, but the damage caused by the latter was significantly less than that caused by the former (**table A3.1**; Bureau of Construction, TMG 2016). Furthermore, the Ring Road 7 Underground Regional Detention Cistern is expected to increase flood management capacity and mitigate floods during concentrated heavy rains in the western wards, as well as their downstream neighborhoods.

Figure A3.5: Flooding in 1993 by Typhoon 11; Water Intake and Situation in Nakano Ward
Source: Bureau of Construction, TMG 2016.

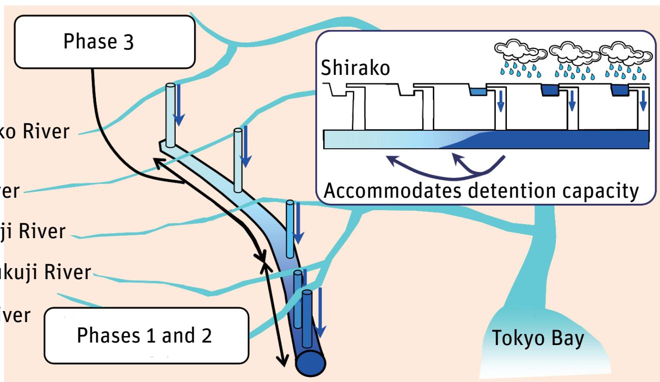


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Figure A3.6: Relationship between Underground Detention Cistern and Five Rivers
Source: Bureau of Construction, TMG n.d.(d).

	Typhoon No.11 (Aug. 27, 1993)	Typhoon Ma-on No.22 (Oct. 9, 2004)
Total rainfall (hourly rainfall)	288 mm (47 mm/hour)	284 mm (57 mm/hour)
Flooded area	85 ha	4 ha
The number of flooded houses (inundation above the ground floor level/basement)	3,117 houses	46 houses

1

Table A3.1: Comparison between Typhoon No. 11 (1993) and Typhoon Ma-on (No. 22; 2004)

Source: Bureau of Construction, TMG 2016.
Note: ha = hectare; mm = millimeter.

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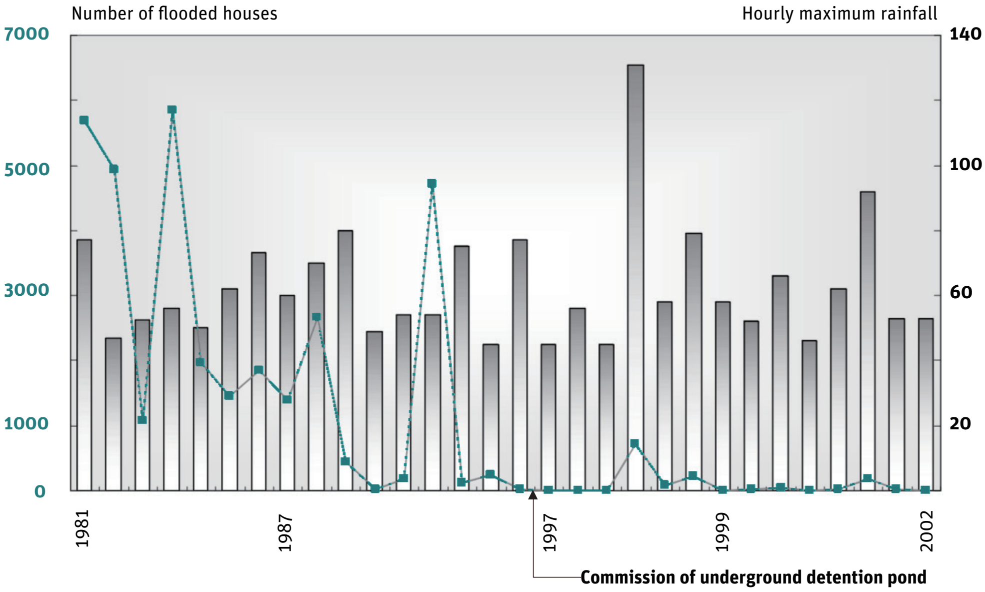

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Figure A3.7: Maximum Rainfall and Number of Buildings Flooded by Kanda River, 1981–2002

Source: MLIT, Kanto Regional Office 2005.


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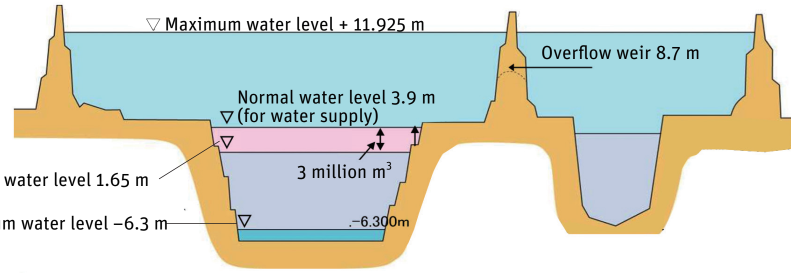
Case 4: Reducing River Flood Risk by Installing a Multipurpose Detention Park and Reservoir: Arakawa River No. 1 Detention Facility

Location:	Saitama City, Saitama Prefecture
Site characteristics:	Urban area (commercial, residential, and public facilities) with low to medium density
Flood management measure(s):	
Flood type	River
Management capacity	Storage: 39 million m^3
	Water supply: Effective capacity 10.6 million m^3
	Treatment capacity: 302,400 m^3/day at advanced wastewater treatment facility[a]
	Arakawa No. 1 detention facility manages 850 cubic meters per second (m^3/s) water volume and is targeted to accommodate a maximum 1-in-200-year storm event[b]
Type of measure(s)	Structural (green)
	Detention park and reservoir
Relevant entities:	
Implementation	Detention facility, treatment plant, reservoir, and associated embankment—national government (river administrator)
	Park facilities (baseball field, jogging and cycling roads, barbeque pits)—Saitama, Toda, and Wako cities
O&M	Same as above
Finance	Same as above
Construction period:	Overall detention facility: 1974–2003
	Saiko Lake (reservoir): 1980–96
Cost:	Construction cost: ¥135.3 billion ($1.23 billion)
	O&M: ¥75.6 million ($687,000) annually (generated by taking the average between 2004 and 2009)[c]
Additional benefits and functions:	Water supply
	Recreational space (public park with sports field)
Sources:	MLIT, Kanto Regional Office 2016, except where otherwise noted.
	a For more details, see MLIT 2010.
	b MLIT 2010.
	c MLIT, Kanto Regional Office 2016.



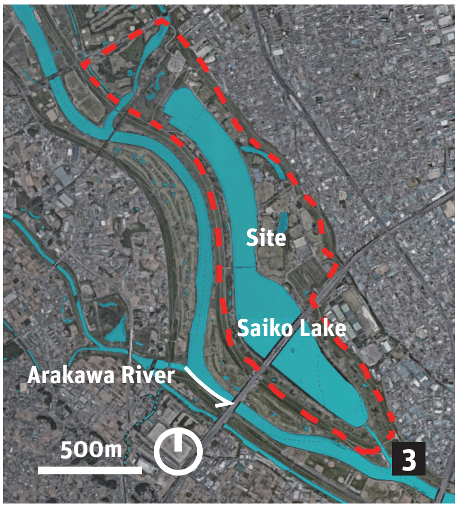


Figure A4.1: Overall View of the Site

Photo Credit: Kenya Endo.

Figure A4.2: Conceptual Diagram of Arakawa River No. 1 Detention Facility

Source: MLIT, Kanto Regional Office 2018.
Note: m = meter; m3 = cubic meter.

Figure A4.3: Site Context

Source: Google Earth. *Note*: m = meter.

Figure A4.4: Sports Field

Photo Credit: Kenya Endo.

Figure A4.5: Urban Context

Photo Credit: Kenya Endo.

Context: Flood Risk

The Arakawa River is a Class A river[7] that flows from **Saitama Prefecture** to Tokyo. Currently, its watershed is shared by 9.7 million residents, and it serves as the region's main potable water supply. In 1947, the Arakawa River experienced a huge flood caused by Typhoon Kathleen that collapsed its embankment, killed 86 people, and damaged nearly 80,000 houses in Saitama Prefecture alone (MLIT, Kanto Regional Office n.d.). Given the socioeconomic damage caused by the devastating floods, as well as growing urbanization and the importance of protecting people and assets downstream, the Japanese government established a comprehensive Arakawa River Basic Construction Plan in 1965,[8] which included measures to install flood management dams upstream and detention facilities midstream, where land was still less developed (MLIT 2007).

In response to these renewed flood management plans, the national government, together with Saitama Prefecture,[9] initiated a project in 1973 to install the Arakawa River No. 1 Detention Facility (Furuichi 2018). The project also addressed the need to convert the region's water source from groundwater to river water, as rapid urbanization and population growth in Tokyo and Saitama Prefecture starting in the late 1950s had led to decreased groundwater levels and land subsidence, which had become a major social issue (MLIT 2015).

Solution: Investment Design and Key Features

Investment Design

Under these circumstances, MLIT began preparing a comprehensive development project for improvement of the Arakawa River in 1974. The construction of Saiko Lake (a 1.18 square kilometer [km^2] reservoir) and Arakawa River No. 1 Detention Park (a multipurpose 4.67 km^2 public park with a sports field and parking lots; **figure A4.4**) was completed in 1996 and 2003, respectively.[10] The storage capacity of the entire facility is 39 million m^3 (MLIT, Arakawa Upstream River Office n.d.[a]; Furuichi 2018). Since completion of the project, the site has served to store and supply sufficient water (**figures A4.6**) to the Tokyo Metropolitan Area and Saitama Prefecture, both of which used to suffer from frequent shortages (MLIT, Kanto Regional Office 2014; Nikkei 2016). The reservoir and park are managed by a number of local governments in the vicinity, including Saitama, Toda, and Wako (Toda City 2017; Wako City 2014).

Key Features

- **Designing a multipurpose and multibenefit investment:** The Detention Facility Utilization Plan was developed to implement proper maintenance and environmental conservation initiatives at the project site, based on discussion among a committee comprising experts and prefecture and city

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7 Class A river systems are those designated by the MLIT minister as important for national land conservation or economic activities. Most Class A rivers have basin areas of 1,000 km^2 or more and are used for water supply and power generation.

8 For more details, see MLIT, Arakawa Upstream River Office n.d.(a) and MLIT, Kanto Regional Office 2007.

9 For more details, see MLIT, Kanto Regional Office 2007.

10 For more details, see MLIT, Arakawa Upstream River Office n.d.(b).

representatives. The plan divided the area into three zones: a nature conservation zone, a water park zone, and an outdoor activity zone. It called for both active use of the riverine environment and protection of the habitats of rare species, such as primrose (Primulaceae spp.).

- **Cost reduction through localizing cut-and-fill earthworks:** By jointly implementing the flood protection measures of the Arakawa River and the development of Saiko Lake, the project cost significantly less than it would have if the two had been carried out separately. About 7,660,000 m^3 of the soil that was excavated from the Saiko Lake development was reused for building embankments along the detention park, saving the ¥24 billion ($218 million) it would have cost to purchase and bring in soil from outside (MLIT, Arakawa Upstream River Office 2004).

Results: Additional Benefits

Arakawa No. 1 Detention Facility has shown remarkable capacity for flood management and water supply. The administrator of the facility publishes a follow-up report every five years, which includes monitoring results pertaining to flood management effectiveness, volume of water supply, quality of water, sedimentation, and the status of the ecosystem and water resources in the reservoir. According to the report, during a flood in August 1999, the water level at the Keisei Oshiage Line Bridge—the lowest water-level monitoring point of the Arakawa River downstream—was 39 centimeters (cm) lower than during the previous flood. Without the development of upstream flood management facilities, the water level would have reached as high as 7 cm just below the bridge (MLIT, Arakawa Upstream River Office 2005). In addition to providing flood management benefits, Saiko Lake supplied approximately 40.5 million m^3 of water to the region over 195 days of water shortage between 2011 and 2016 (MLIT 2016).[11]

Figure A4.6: Detention Facility under Normal and Flood Conditions

Source: MLIT, Kanto Regional Office 2018.

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11 For more details, see MLIT 2016.

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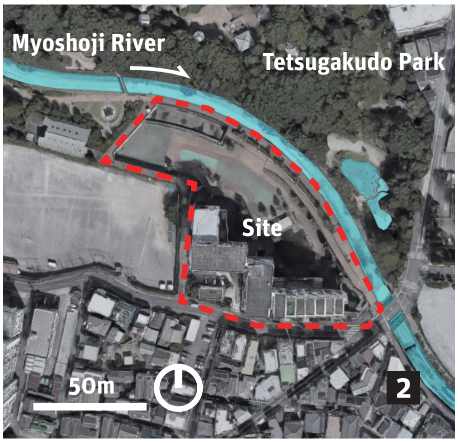
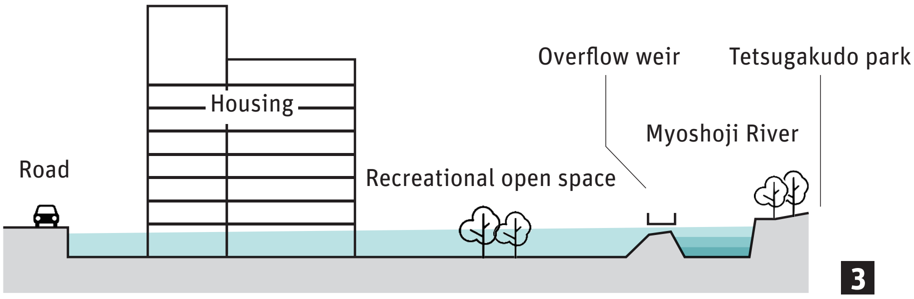
Case 5: Reducing River and Surface Water Flood Risk through Cost Sharing for O&M: Tetsugakudo Park Collective Housing and Myoshoji River No. 1 Detention Pond

Location:	The Myoshoji River between Shinjuku Ward and Nakano Ward in the Tokyo Metropolitan Area
Site characteristics:	Dense urban area with assets and population highly concentrated near residential, industrial, commercial, office, and public areas. A large plot of land became available when the factory relocated.
Flood management measure(s):	
Flood type	River and surface water
Management capacity	Tetsugakudo Park Collective Housing: 163 household development
	Myoshoji River No. 1 Detention Pond: 30,000 m^3 with management capacity of 50 mm/hour
	Park: 7,600 square meters (m^2) of permeable surface
Type of measure(s)	Structural (green and gray)
Relevant entities:	
Implementation	Tetsugakudo Park Collective Housing: Urban Renaissance Agency (UR)
	Myoshoji River No. 1 Detention Pond: TMG
	Park: Shinjuku and Nakano Ward
O&M	Same as above
Finance	Same as above
Construction period:	1984–87
Cost:	Total development cost: ¥10.4 billion ($94.5 million)[a]
Additional benefits and functions:	Increase in public recreation space
	Housing development
Sources:	UR 2018, except where otherwise noted.
	a UR n.d.



Context: Urban Development and Flood Risks

Rapid development over the years has made the Myoshoji River, which used to have fields and forests in its basin, into a typical urban river. With dense urban neighborhoods within its watershed, the river often overflows due to the immense volume of stormwater that flows into it during heavy rain (UR 2018). During the flood in 2005, for example, heavy rain damaged over 3,000 houses in **Suginami and Nakano wards** (Bureau of Construction, TMG 2015). The region was able to cope with about 30 mm/hour rainfall as of 1975, thanks to continuous flood mitigation efforts, but the amounts of torrential rainfall nowadays often exceed that capacity. In light of this, the river administrator had set as a goal for the immediate future the capacity to cope with 50 mm/hour rainfall; however, given that meeting that goal would drain water toward the downstream area, river



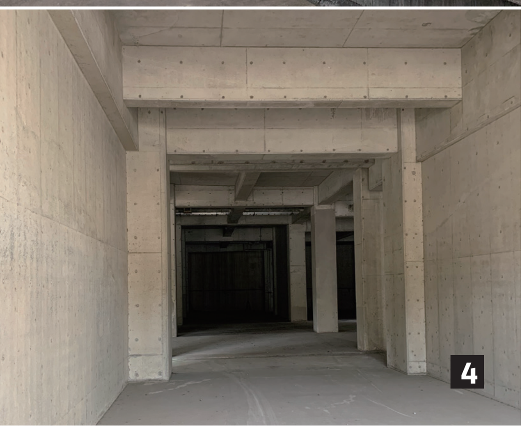


Figure A5.1: Overall View of the Site
Photo Credit: Kenya Endo.

Figure A5.2: Site Context
Source: Google Earth. Note: m = meter.

Figure A5.3: Conceptual Diagram of the Infrastructure
Source: Modified based on information from UR (2018).

Figure A5.4: Park and Pilotis Spaces at the Site
Photo Credit: Kenya Endo.

authorities of TMG have aimed to manage flood risks through the installation of detention ponds along the river, in conjunction with urban development initiatives.

Solution: Investment Design and Key Features

Investment Design

In response to new urban development and the increasing need for flood risk management, TMG, Shinjuku and Nakano wards, and the UR, a housing developer, launched a joint initiative in 1984. With a shared incentive to implement a project that would utilize land and reduce life-cycle costs effectively, TMG asked Nakano and Shinjuku wards and UR to collaborate on a multipurpose development that would combine residential development (led by UR) with the construction of aboveground detention ponds (led by TMG) and a public park (led by Shinjuku and Nakano wards). The total development area was to be approximately 11,000 m^2, with a water detention capacity of approximately 30,000 m^3 (**figure A5.3**).

TMG developed, along with the wards, the detention pond that improved the park, while UR facilitated development of a convenient and attractive housing development to ensure profitability of the overall development project. The collaboration of the four diverse stakeholders in the design implementation resulted in a multifunctional and multibenefit project.

The detention pond has two layers of water storage. As the water level of the Myoshoji River rises, the first storage layer takes surplus water flow into the middle of the detention pond. When the middle becomes full, surplus water then flows into the part that is used in normal times as park and pilotis spaces for the residential area (**figures A5.3** and **A5.4**). The detention pond can accommodate a rainfall of 30 mm/hour.

Key Features

- **Shared roles and responsibilities for implementation and O&M resulting in cost savings:** TMG tried to make use of the open space created after a factory relocation to install detention ponds, but the high price of the land presented a challenge. Furthermore, devoting the space solely to the purpose of water management represented an underutilization of this valuable land. In addition, the cost of the land made it difficult for the ward governments to finance the development costs on their own. Expanding the use of the land to other purposes, therefore, was important, as many people would have an interest in financing the construction (thus reducing the cost per investor), and O&M responsibilities could be shared among the stakeholders (UR 2018). To this end, TMG, Nakano and Shinjuku wards, and UR developed a management agreement that aimed to designate almost the entire development site as a "river area"; clarified who would manage the areas with multiple land use types; clarified the functions of the detention ponds and recreational park; and, last, stipulated that none of the four stakeholders would own the property rights or the exclusive usage rights to the river (UR 2018). As per this agreement, TMG and the two wards became responsible, respectively, for O&M of the detention ponds and the park. UR would be responsible for O&M of the piloti on the ground-floor level of the building and of the fence around it under normal circumstances. The agreement clearly stated that, after floods, the two wards would remove debris and mud from gutters and

Stakeholder	Land Cost Sharing	Land Use	Land Ownership
Tokyo Metropolitan Government	42%	Entire site (river area)	-
Nakano and Shinjuku Ward Authorities	33%	66%	50%
Urban Renaissance Agency	25%	Approximately 33% (entire site is subject to a floor area ratio)	50%

1

Table A5.1: Land Cost Sharing, Use, and Ownership by Stakeholders
Source: Based on UR (2018).

clean the fence. In addition, it was agreed that an administrator from UR would activate alarms for evacuation, if necessary. **Table A5.1** shows further cost- and role-sharing arrangements. As a result of these arrangements, costs were significantly reduced for the individual stakeholders, as compared to what they would have been had they implemented the project individually.

- **Effectiveness of governance and coordination mechanisms across city boundaries:** The location of the detention pond between Nakano and Shinjuku wards complicated its development and O&M management. To advance the development of collective housing and detention ponds, the two wards and UR reached an agreement that clearly defined in advance their duties and roles for sustainable construction and O&M, as described above.

Results: Large-Scale Flood Management Investment Enabled in High-Value Land

The investments in Tetsugakudo Park Collective Housing and Myoshoji River No. 1 Detention Pond have contributed significantly to flood management in the area. Records dating back to 1995, for example, show that the flood waters are managed within the park and the piloti spaces about twice a year, with a maximum depth of 230 cm. The detention pond has also repeatedly helped mitigate flood damage in the downstream area in central Tokyo (UR 2018).

Financing large-scale flood management facilities in urban centers with high-value land may be difficult if carried out by the public sector for public use alone. The case of Tetsugakudo Park Collective Housing and Myoshoji River No. 1 Detention Pond illustrates how partnership between local governments, as well as with a housing developer, to share the cost and responsibilities for implementation and O&M among the various stakeholders can enable the implementation of flood management facilities in high-value land areas in urban centers.

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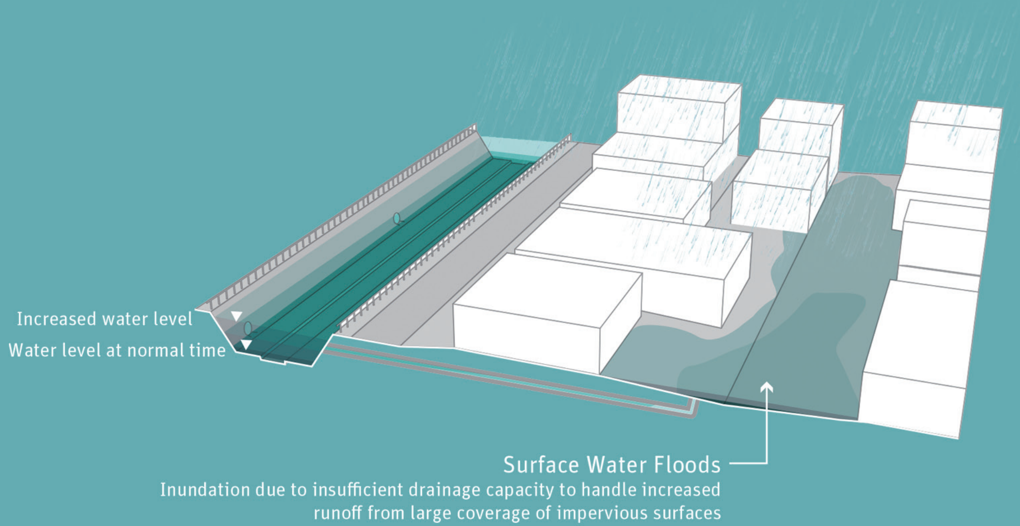
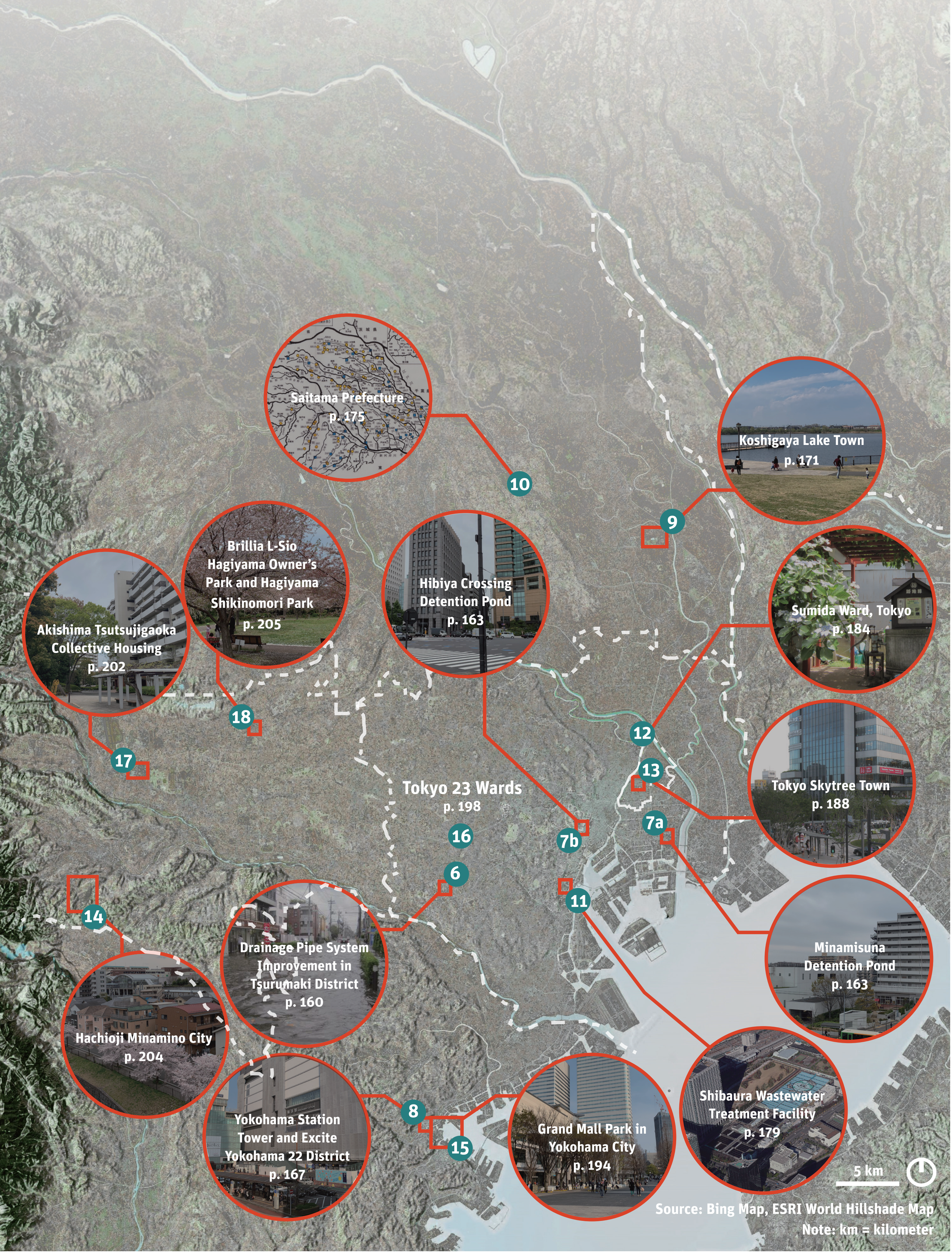
Surface Water Floods




Saitama Prefecture
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10
Koshigaya Lake Town
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Brillia L-Sio Hagiyama Owner's Park and Hagiyama Shikinomori Park
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Hibiya Crossing Detention Pond
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Tokyo Skytree Town
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Minamisuna Detention Pond
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Yokohama Station Tower and Excite Yokohama 22 District
p. 167
8
15
Grand Mall Park in Yokohama City
p. 194
5 km
Source: Bing Map, ESRI World Hillshade Map
Note: km = kilometer

Figure A6.1: Flooded Tsurumaki District on July 23, 2013
Source: Setagaya Ward 2016.

Case 6: Reducing Surface Water Flood Risk with an Underground Stormwater Management Facility: Drainage Pipe System Improvement, Tokyo

Location:	Along Jakuzuregawa River, which runs through Tsurumaki District, Setagaya Ward, and Kami-Meguro District, Meguro Ward, in central Tokyo
Site characteristics:	Located in a highly developed area in central Tokyo, with main railway stations and surrounded by thriving commercial areas
Flood management measure(s):	
Flood type	Surface water
Management capacity	Designed to accommodate maximum rainfall of 75 mm/hour
	Initial 2.8 km under Phase 1 estimated to have additional 42,000 m^3 storage capacity
Type of measure(s)	Structural (gray)
	Underground stormwater management facility (drainage pipe system)
Relevant entities:	
Implementation	Mainly the Sewerage Department of TMG with support from the Setagaya and Meguro ward governments
O&M	Same as above
Finance	Same as above
Construction period:	Phase 1 (initial 2.8 km): 2016–20[a]
	Phase 2 (remaining 4 km): To be determined
Cost:	Approximately ¥6.7 billion[b] ($61.3 million) for Phase 1
Additional benefits and functions:	Not applicable
Sources:	Bureau of Sewerage, TMG 2017.
	a Setagaya Ward 2016.
	b From bidding disclosure data available at http://oss.avantage.co.jp/bid/?p=536257; http://oss.avantage.co.jp/bid/?p=679307; http://oss.avantage.co.jp/bid/?p=310002.

Context: Urban Development and Flood Risk

The highly concentrated urban neighborhoods of Tokyo place great priority on saving people and assets from surface water floods. The massive network of existing infrastructure at the subsurface level (such as metro and utility lines), as well as dense built-up areas at the ground level, make structural (gray) measures with minimum impact to the existing urban settings the preferred approach.

Meguro and Setagaya wards are centrally located within the Tokyo Metropolitan Area, where houses and commercial developments are densely built and land values are high. With the financial and technical leadership of TMG, the two wards constructed a combined sewer and rain management system along the Jakuzuregawa River, 9.7 km in length (Watanabe 2015).

This system, which served as an exposed drainage channel until it was covered in 1955, drains stored water after a rainfall to lower the water level of the Meguro River. With rapid urban development, two additional water detention facilities (with storage capacity of 12,000 m³) were constructed.

Floods have been increasing in frequency and magnitude, however. During a concentrated heavy rain in July 2013, more than 60 buildings were inundated along the sewerage system.[12] **Figure A6.1**, for instance, shows flooding in Tsurumaki District on July 23 of that year, a result of a 66 mm/hour storm (Setagaya Ward 2016).

In response to such intense rainfall, TMG, together with central wards in Tokyo with high urbanization and flood risks, designated areas that urgently required improvement to and retrofitting of their flood management facilities to manage 75 mm/hour rainstorm events.[13] Flood management priority areas, including Setagaya and Meguro wards, were identified, based not only on their high flood risks and the density of their urban populations and assets, but also on the existence of flood management infrastructure that could be effectively upgraded. Among the characteristics of existing infrastructure in priority zones were (i) drainage systems laid not far below ground level, (ii) heavily urbanized neighborhoods in the surrounding areas, and (iii) valley-like conditions where a high volume of runoff came together all at once. These sites included Tsurumaki District in Setagaya Ward and Kami-Meguro District in Meguro Ward.

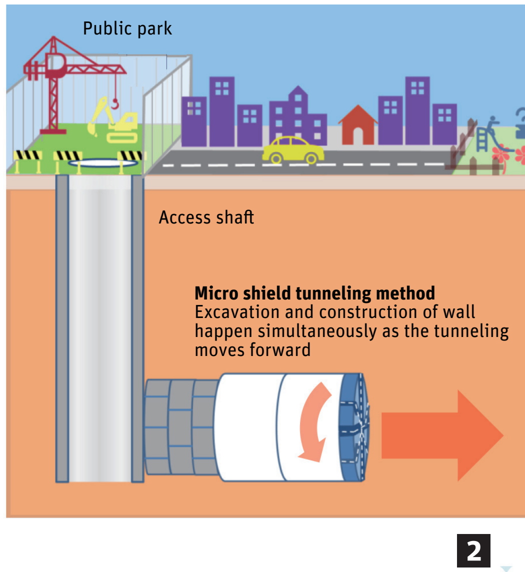
Solution: Investment Design and Key Features

Investment Design

Construction of an additional channel underneath the original combined sewer and rain management system along the Jakuzuregawa River was initiated in 2017. The additional channel is approximately 5 m in diameter and 6.8 km long (Setagaya Ward 2016). The initial 2.8 km is estimated to have 42,000 m³ of additional storage capacity, which will contribute toward achieving TMG's target of managing intense storms with rainfall up to 75 mm/hour.

Key Features:

- **Little impact during underground construction work:** The "micro shield tunneling method" (see the conceptual diagram in **figure A6.2**) was utilized to construct additional water pipes running along the underground stormwater drainage system. In Tsurumaki's case, the new pipes were laid approximately 60 m below ground level (**figure A6.3**). In addition, access shafts for the construction work were placed in public parks, which minimized the impacts of noise, vibration, and dust on the surrounding neighborhoods. Given the low construction impact, TMG is able to construct two pipes simultaneously, which shortens the total construction time from the 6.5 years planned to 4.5 years.
- **Phased and modular construction process:** Extensive underground work often requires long periods to complete. In light of the urgent need to manage surface water as quickly as possible, TMG will implement the underground channel construction in three small segments (including two segments in Phase 1 that will be implemented simultaneously), from upstream to



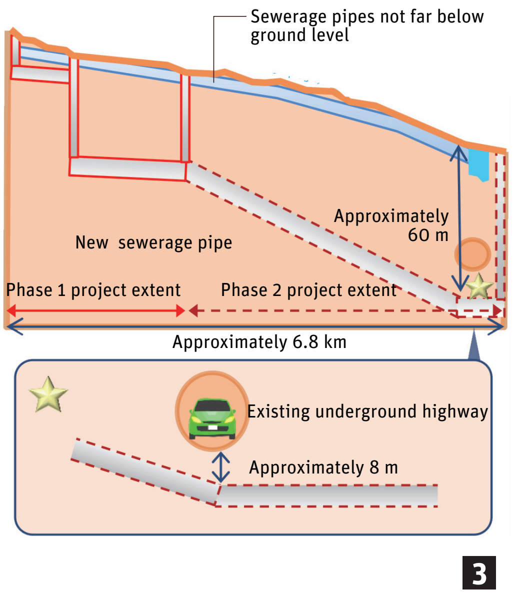


Figure A6.2: Conceptual Diagram of Micro Shield Tunneling Method

Source: Bureau of Sewerage, TMG 2018.

Figure A6.3: Conceptual Diagram of Construction Work for New Sewerage Pipes at Tsurumaki District

Source: Bureau of Sewerage, TMG 2018.
Note: km = kilometer; m = meter.

12 For more information, see TMG (2015).
13 For more information, see TMG (2018).

downstream. As soon as construction of one segment is completed, the facilities can go into operation managing surface floods, without the need to wait for the entire project to be finished (Bureau of Sewerage, TMG 2018).

Results: Efficient Infrastructure Construction

The adoption of the micro shield tunneling method enabled efficient construction of the underground surface water management facility by shortening the construction time for the additional drainage pipes and making available the additional flood management capacity as quickly as possible. This was possible because the technological innovation allowed for the complex underground construction work to be carried out with minimal noise, shaking, and aboveground space, thus making possible the simultaneous construction of two segments of the pipes. Despite the high cost, highly dense urban centers with immediate flood management needs can benefit from this construction method, given the potential savings in time and disruption of existing economic, infrastructure, and social activities above- and belowground.

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Case 7: Reducing Surface Water Flood Risk by Installing an Underground Stormwater Management Facility with Other Public Facilities: **Minamisuna Detention Pond (7a) and Hibiya Crossing Detention Pond (7b)**

Location:	Minamisuna and Hibiya are neighborhoods located in Koto and Chiyoda wards, respectively, in the Tokyo Metropolitan Area.
Site characteristics:	Minamisuna: Residential district; Hibiya: Central business district
Flood management measure(s):	
Flood type	Surface water
Management capacity	Minamisuna: Stormwater storage capacity of 25,000 m^3 (length 62 m × width 46 m × depth 9 m)[a]
	Hibiya: Stormwater storage capacity of 3,400 m^3 (width 9.9 m × length 47.7 m × depth 6.8 m)
Type of measure(s)	Structural (gray)
	Underground stormwater management facility (detention pond)
Relevant entities:	
Implementation	Minamisuna: Detention pond—Bureau of Sewerage, TMG with technical and financial support from MLIT; housing development—Tokyo Metropolitan Housing Supply Corporation; bicycle parking—Koto Ward
	Hibiya: Detention pond—Bureau of Sewerage, TMG with technical and financial support from MLIT; road upgrade—MLIT
O&M	Same as above
Finance	Same as above
Construction period:	Minamisuna: Detention pond began operation in 2006; overall Shinsuna Land Readjustment Project implemented 1997–2004[b]
	Hibiya: Detention pond construction: 2005–07; common tunnel construction in Hibiya started in 1987
Cost:	Minamisuna: Detention pond—approximately ¥10 billion ($85 million)[a]; Shinsuna Land Readjustment Project—approximately ¥16.8 billion ($152 million)[b]
	Hibiya: not available
Additional benefits and functions:	Minamisuna: 107 housing units, bicycle parking, parks, and other public amenities aboveground[c]
	Hibiya: Mitigation of heat island effect
Sources:	Kamata 2006, except where otherwise noted.
	a Bureau of Sewerage, TMG 2009.
	b Bureau of Urban Development, TMG 2004.
	c Tokyo Metropolitan Housing Supply Corporation, n.d.

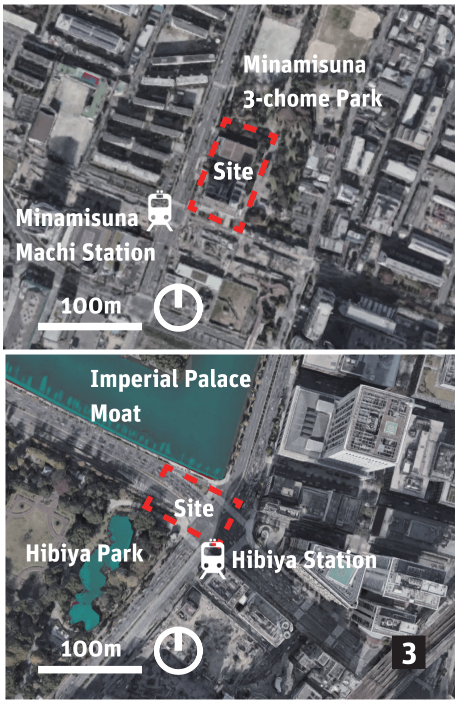

Figure A7.1: Overall View of the Site: Minamisuna
Photo Credit: Kenya Endo.

Figure A7.2: Overall View of the Site: Hibiya Crossing
Photo Credit: Kenya Endo.

Figure A7.3: Minamisuna and Hibiya Site Contexts
Source: Google Earth. *Note*: m = meter.

Context: Urban Development and Flood Risk

Minamisuna District is located on reclaimed land below sea level in **Koto Ward**, Tokyo, and has historically suffered from severe flood damage to people and assets. Hibiya District is the heart of the central business district in Tokyo and the location of various highly valued structures and services. There, dense development with limited infiltration capacity has resulted in frequent inundation of the area around Hibiya Crossing, disrupting activities in the surrounding areas. During Typhoon Ma-on (No. 22) and Typhoon Tokage (No. 23) in October 2004, for example, serious flood damage to roads halted traffic in Hibiya Crossing and disabled the connectivity of this important transportation hub (**figure A7.4**).

In both districts, key public infrastructure facilities were in need of upgrading or under development, while the need to enhance their surface flood management capacities also increased. Minamisuna District is the location for Tokyo's second oldest sewerage management facility, which was established in 1930 as a pumping station (Chida 2012). Between 1997 and 2004, the Shinsuna Land Readjustment Project, a large urban redevelopment initiative, was implemented in the Shinsuna area, which includes Minamisuna, and a sewerage management infrastructure upgrade was implemented in conjunction with it (Bureau of Urban Development, TMG 2004). In Hibiya, as part of the national effort underway since 1963 to increase the construction and O&M efficiencies of underground infrastructure (such as electricity, water, communication, and sewerage systems), MLIT has been working to centralize such lifeline infrastructure through the construction of a common tunnel.[14] The work is considered especially important in high-density urban centers of the Tokyo metropolitan area, like Hibiya. Led by MLIT, construction of the common ditch, which is 6.7 m in diameter and 1,450 m long, started in Hibiya Crossing in 1989.

Solution: Investment Design and Key Features

Investment Design

As noted above, both underground surface flood management facilities in Minamisuna and Hibiya were constructed in conjunction with the development of another public facility as part of an initiative led by TMG's Bureau of Sewerage to meet its flood management goal of handling rainfall of 75 mm/hour in the central wards of Tokyo. In Minamisuna, MLIT constructed a detention pond 20 m belowground with a storage capacity of 25,000 m^3, with a public housing complex, public bicycle parking, and park developed aboveground as part of the larger urban Shinsuna Land Readjustment Project (**figures A7.5** and **A7.6**). In Hibiya, TMG, in partnership with MLIT, constructed a detention pond[15] with a storage capacity of 3,400 m^3 under a common lifeline infrastructure tunnel that runs beneath a national road (**figure A7.7**).

14 Also referred to as "Hibiya Common Ditch" (Kamata 2006).

15 Also called a "sewerage stormwater regulating reservoir" (Kamata 2006), but to maintain consistency in terminology throughout the Knowledge Notes, we refer to the facility in Hibiya Crossing as a detention pond.

Key Features

- **Cooperation with other public facilities and stakeholders:** When planned strategically, engagement of various stakeholders in designing and implementing urban flood management facilities can save significant time and cost. For construction of the detention pond in Minamisuna, the Bureau of Sewerage partnered with other urban development, environmental, and social development bureaus of TMG, as well as Koto Ward, to design the multiple-use development of the limited land area to maximize public amenities and functions. In Hibiya, MLIT and TMG's partnership is estimated to have reduced the cost of the detention pond by about 30 percent and the time to construct it by two years (Kamata 2006).
- **Layering belowground and aboveground benefits and use:** Development of flood management facilities in a high-density urban center requires efficient use of limited space, both above- and belowground, for flood management as well as for other benefits and uses. In Minamisuna, the belowground area is utilized for flood management, while the aboveground area hosts various public facilities, such as high-rise public housing, a public childcare center and park, and bicycle parking, providing various social and environmental benefits (Suido Sangyo Shimbun 2006). In Hibiya, collaboration between TMG and MLIT led to the utilization of the belowground space for development of a stormwater detention pond and tunnel to manage infrastructure utility lines centrally and the aboveground space for a national road. The water stored in the detention pond is also pumped up to a sprinkler system to water plants along the road, where the green vegetation serves as an important heat island mitigation mechanism during the summer (Kamata 2006).

Results: Cost Savings through Partnership

While underground stormwater management facilities can provide significant capacity for surface flood management, their construction and O&M can be extremely high, as can the opportunity cost to utilize valuable and limited space in high-density urban areas. The successful projects around the **Minamisuna** and **Hibiya** detention ponds demonstrate that, while the structural development of such large facilities can be extremely costly if done for a single purpose and by one institution, developing them in partnership can achieve significant savings through shared construction costs and responsibilities and/or reduced construction time.

Figure A7.4: Flooding in Hibiya, October 2003

Source: Kamata 2006.

Figure A7.5: The Minamisuna Neighborhood

Photo Credit: Kenya Endo.

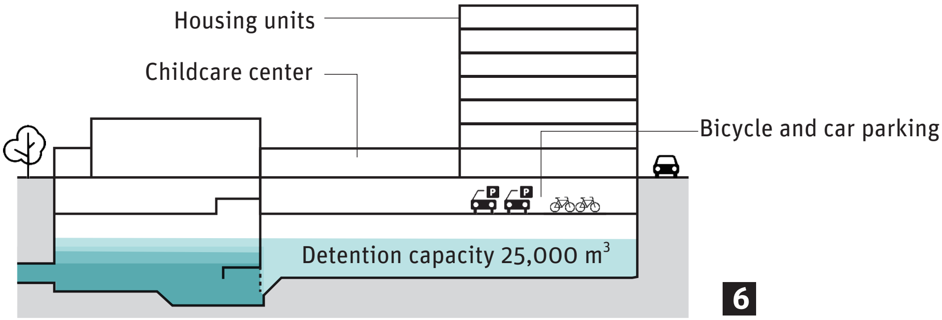

Figure A7.6: Conceptual Diagram of the Minamisuna Underground Stormwater Management Facility (Cistern)

Source: Developed based on information from MLIT (2006). *Note*: m^3 = cubic meter.

Figure A7.7: Conceptual Diagram of the Hibiya Underground Stormwater Management Facility (Cistern)

Source: Kamata 2006. *Note*: m^3 = cubic meter.

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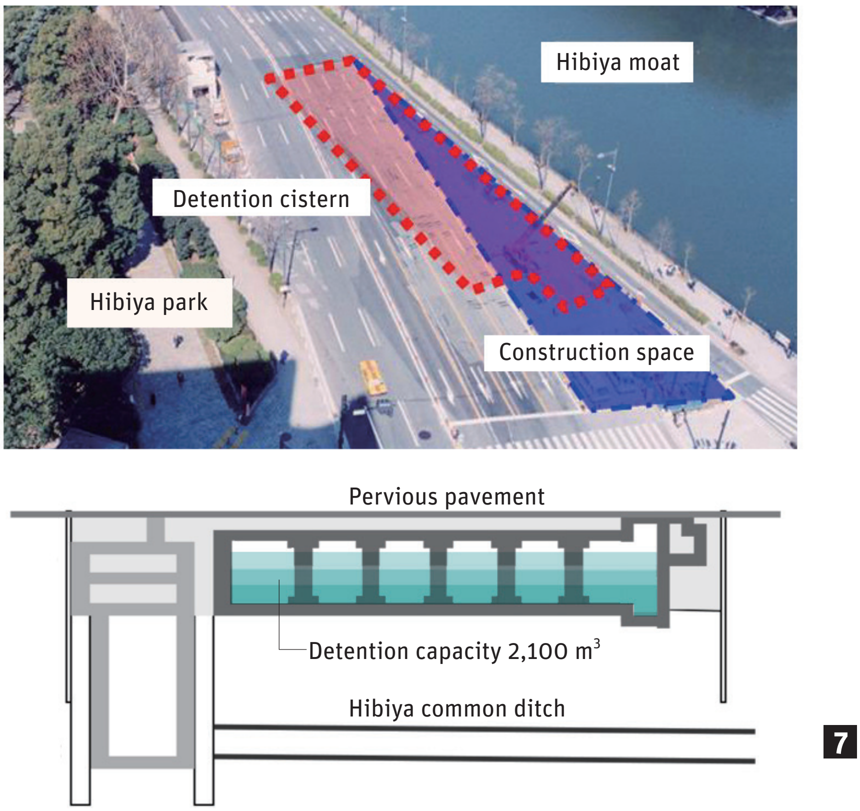
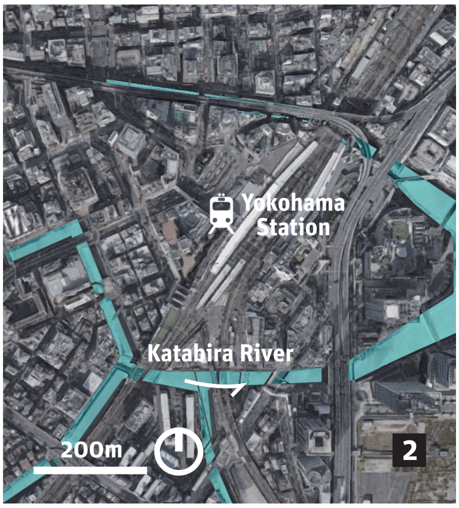
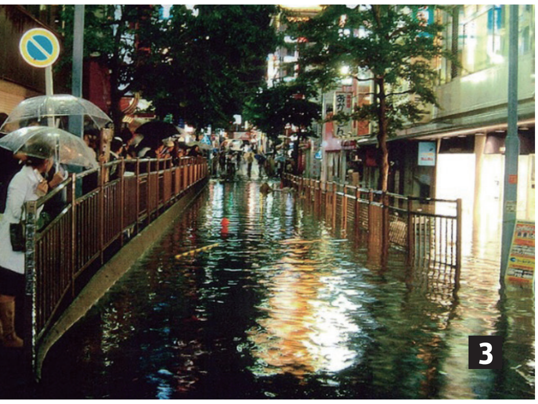


Case 8: Reducing Surface Water Flood Risk by Installing an Underground Stormwater Management Facility: Yokohama Station Tower and Excite Yokohama 22 District

Location:	Yokohama Station is located in Yokohama City, a highly concentrated urban area in Kanagawa Prefecture
Site characteristics:	A gateway to the city center, which 2.2 million people visit every day, the area features many commercial buildings. Around 2.2 million passengers pass through Yokohama Station in a day.
Flood management measure(s):	
Flood type	Surface water
Management capacity	Yokohama Station Tower underground detention cistern capacity: 170 m^3, contributing toward achievement of the citywide flood management target to accommodate rainfall of 82 mm/hour (1-in-50-year storm event). Current drainage facility achieves 60 mm/hour of storm water management. An additional 14 mm/hour to be initiated by Yokohama City's drainage capacity upgrade work. A further 8 mm/hour are to be achieved by public-private partnership efforts.
Type of measure(s)	Structural (gray) Underground stormwater management facility (cistern)
Relevant entities:	
Implementation	East Japan Railway Company (JR East) in partnership with Yokohama City
O&M	Same as above
Finance	Underground stormwater management facility—subsidies jointly provided by MLIT and Yokohama City to finance one-third of the total cost each, with JR East self-financing the remaining one-third.
Construction period:	2016–20 (scheduled)
Cost:	Construction cost for two Yokohama Station Tower buildings: ¥91.8 billion ($835 million) for a building 135 m tall with 26 stories and a building 31 m tall with 9 stories[a]
	Underground stormwater management facility—information not available
Additional benefits and functions:	Urban redevelopment Private sector engagement
Sources:	Tanigawa 2017; Climate Change Adaptation Information Platform 2018; Japan Skyscraper n.d., except where otherwise noted.
	a *Daily Engineering and Construction News* 2017.





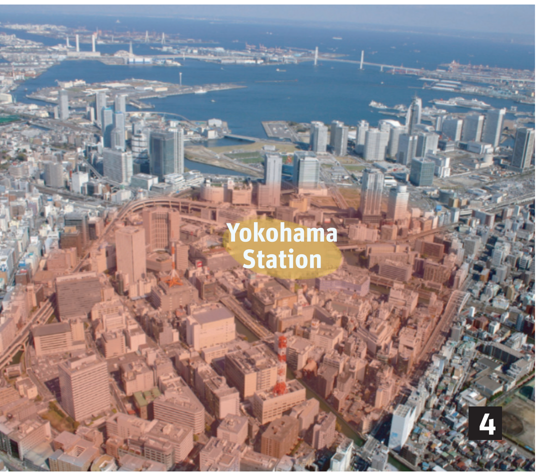


Figure A8.1: Current View of Yokohama Station
Photo Credit: Kenya Endo.

Figure A8.2: Site Context
Source: Google Earth. *Note*: m = meter.

Figure A8.3: Flood Damage in the Yokohama Station Area (Typhoon Ma-on in 2004)
Source: Ishii 2019.

Figure A8.4: Area Targeted by Excite Yokohama 22
Source: Urban Development Bureau, Yokohama City 2013.

Context: Surface Flood Risk at a Highly Urbanized Transportation Hub

The second-largest city in Japan with a population of 3.7 million, **Yokohama City** is adjacent to Tokyo, with easy access to Haneda International Airport. Yokohama Station, which functions as a hub station in the region, is used by approximately 2.2 million people per day and is a gateway to the Yokohama central business district. The station is, however, located in a lowland area close to Yokohama Bay and is surrounded by the Shintama and Katabira rivers; hence, the area risks serious flooding in the event of concentrated heavy rains.

The Katabira River, for instance, flows approximately 200 m south of the station, and its valley-like microtopography acts as a basin. When Typhoon Ma-on (with rain at a maximum intensity of 76.5 mm/hour) passed by in October 2004, the river overflowed and inundated 1,007 residential and commercial buildings in the vicinity (**figure A8.3**). Underground areas incurred significant damage as the water cascaded down to the basement-level shopping arcades, and the effects of the flooding on electrical facilities hindered evacuation procedures. Also presenting challenges to evacuation in the station and surrounding areas were aging buildings (vulnerable to earthquakes), a shortage of open space for evacuation, and a lack of risk communication and wayfinding measures that could effectively guide the public in case of emergency.

To manage the flood risks in the lower-lying area around Yokohama Station, water is drained to the surrounding rivers by three rainwater pumping stations and three small-scale pumping stations. These pumps can manage a storm with a 10-year return period, with rainfall intensity of approximately 60 mm/hour. Additionally, for districts located on high ground, gravity drainage is installed, designed for storms with 5-year return periods (approximately 50 mm/hour).

With the growing awareness of climate change and rising disaster risks,[16] Yokohama has taken a stepwise approach to increasing its flood management capacity. Combining the need for improving flood management with the implementation of a comprehensive redevelopment master vision, “Excite Yokohama 22,” Yokohama City established a town development plan in 2009, focused on the integration of flood management measures with the town planning process in the 140 ha area highlighted in **figure A8.4**.

Solution: Investment Design and Key Features

Investment Design

The Excite Yokohama 22 town development plan defines a vision and guiding principles for the district’s future (Urban Development Bureau, Yokohama City 2012). A key pillar is the importance of incorporating disaster prevention measures (against flooding, earthquake, and tsunami) comprehensively within the district’s town planning process. For flood risk mitigation, the plan specifies that (i) private redevelopment projects more than 5,000 m^2 in area are required to install stormwater storage facilities that can handle more than 200 m^3 of excess stormwater; (ii) private and public sectors need to raise their ground-floor elevations to 3.1 m above sea level; and (iii) the target for Yokohama City’s

16 Since 1975, the overall frequency of rainfall above 50 mm/hour has increased by 30–40 percent (Ishii 2019).

sewerage and drainage capacity is to be increased to accommodate a rainfall of 74 mm/hour, equivalent to a 1-in-30-year rainfall event, through the laying of new drainage pipes deep underground and the installation of new pump facilities.

In addition to public sector efforts to enhance flood management capacity to this level, the city partnered with the private sector to manage up to 82 mm/hour or 1-in-50-year flood events in the central area near Yokohama Station. MLIT, Yokohama City, and private developers are collaborating on Yokohama Station Tower, a flagship project of this initiative that is expected to be completed in 2020. For it, a stormwater detention cistern with 170 m^3 capacity is under construction below basement level 3 of a mixed-use 26-story building (Climate Change Adaptation Information Platform 2018).

Key Features

- **A national policy enabling public-private partnership initiatives for installing stormwater management facilities:** MLIT designated Yokohama Station and its vicinity as the first "Flood Mitigation Focus Area" (a 30 ha site) in Japan. This new approach, established under the revision of the National Sewerage Law in July 2015, promotes the installation of stormwater storage facilities in large-scale private redevelopment projects through public-private partnerships (**figure A8.5**). The revision of the national act in 2015 led in turn to the revision of Yokohama City's bylaws in 2016, allowing for the first-ever designation of a flood damage control area in Japan in January 2017 and initiation of the collaborative Excite Yokohama 22 project in February 2017.
- **Cost-sharing among MLIT, Yokohama City, and private developers:** This policy obliges private developers to install and conduct O&M work on the stormwater storage facilities in their developments but at the same time enables them to receive subsidies for the work they do (for example, the construction of the underground cistern) from the national and local governments (Tanigawa 2017; MLIT 2016). Established in 2016, the subsidy program is available (i) to business operators conducting large-scale developments of 5,000 m^2 or more in area; and (ii) for the installation of 200 m^3 of management capacity per 1 ha of land area. For these projects, the private developers pay one-third of the total installation cost, with the remaining two-thirds subsidized by the national government and Yokohama City (one-third each). In addition to the subsidies, other incentives included tax reduction for installing larger storage capacity (300 m^3 or more; Ishii 2019).

Results: Cost Savings through Partnership

Through the combined efforts of the public and private sectors, Yokohama City was able to meet the stormwater management target and lower the flood risks for its newly redeveloped site. The benefits for private developers were (i) subsidies offered by the national and city governments; (ii) enhanced mitigation of surface water flooding; (iii) potential increase in property value; and (iv) an opportunity to engage with the community as a form of corporate social responsibility. By providing financial incentives to the private developers for both installation and O&M works, Yokohama City was able, in return, to raise its stormwater management capacity goal in 2017 to 82 mm/hour, which is equivalent to a 1-in-

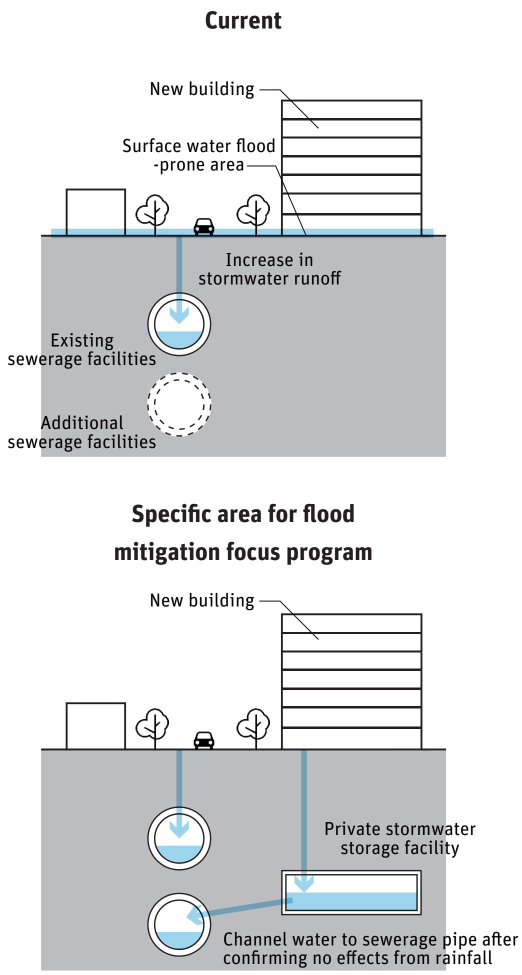


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Figure A8.5: Conceptual Diagram of Flood Mitigation Focus Area Program

Source: Modified based on information from MLIT (2016).

50-year rainfall.

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Case 9: Reducing Surface Water and River Flood Risk by Integrating a Reservoir into Large-Scale Urban Development: Koshigaya Lake Town

Location:	Koshigaya City, Saitama Prefecture, which also serves as a suburb of Tokyo, approximately 20 km north of the Tokyo city center
Site characteristics:	A large-scale (225.6 ha) new town development site surrounded by a low-density urban area and agricultural lands
Flood management measure(s):	
Flood type	River and surface water
Management capacity	1.2 million m^3 of water detention capacity in 39.5 ha of an aboveground detention reservoir to temporarily manage rainwater that falls on-site but also to avoid river overflow by detaining rainwater flowing into the Nakagawa and Motoarakawa rivers.
	In a 61.5 mm/hour heavy rainfall event in 2009 in Koshigaya City, the reservoir effectively avoided inundation of the surrounding area.
Type of measure(s)	Structural (green)
	Reservoir
Relevant entities:	
Implementation	Urban Renaissance Agency (UR)
O&M	The reservoir and facilities associated with flood management arecomprehensively managed by Koshigaya City; park spaces surrounding the reservoir are managed by the city's tourism association
Finance	UR, Saitama Prefecture, MLIT
Construction period:	1999–2014
Cost:	Overall construction of reservoir and conduit: ¥51.6 billion ($469 million)
	Reservoir: ¥39.6 billion ($338 million) shared among UR (44 percent), MLIT (28 percent), and Saitama Prefecture (28 percent)
	Conduit: ¥12 billion ($103 million) by MLIT river administrators
	Overall Koshigaya Lake Town development: ¥80.6 billion ($733 million)
Additional benefits and functions:	Urban development, through development of new housing, commercial activities, and other public services
	Attractive living environment with access to a lake and associated water sports
	Community awareness and efforts toward disaster risk management and environmental conservation
Sources:	Koshiyaga City 2015b.

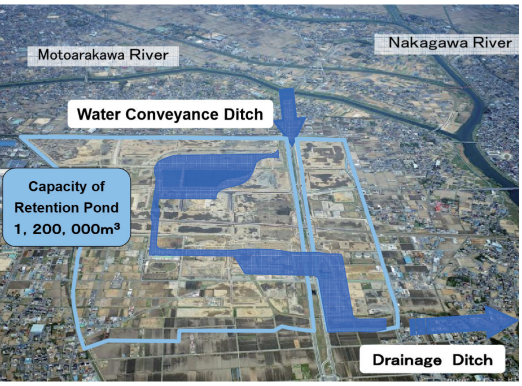

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Figure A9.1: Overall View of the Site

Photo Credit: Kenya Endo.

Figure A9.2: Site Context

Source: Google Earth. *Note*: m = meter.

Figure A9.3: Conceptual Diagram of the Reservoir and Its Relationship to the Larger Context

Source: Yoshimura 2016. *Note*: m^3 = cubic meter.

Context: Urban Development and Flood Risks

Since 2008, the **Koshigaya Lake Town** area has grown rapidly as a residential neighborhood with good access to major urban centers. Koshigaya Lake Town stands 20 km north of Tokyo's city center, on what used to be agricultural land adjacent to the Nakagawa River and the Motoarakawa River. Its vulnerability to frequent river floods left the site long undeveloped, despite its easy access from nearby large cities. For this reason, a new compact urban development project was initiated there in 1999 by combining flood mitigation measures with a housing development.

Solution: Investment Design and Key Features

Investment Design

Koshigaya Lake Town, a 225 ha urban development project led by the Urban Renaissance Agency (UR), was carried out from 1999 to 2014. The vision of creating an attractive living environment while mitigating flood risks was developed in collaboration with MLIT (as the national river administrator) and the Saitama prefectural government (as the local river administrator). The key intervention was the installation of a 39 ha detention reservoir within the development site to store water on occasions when the water level of the Motoarakawa River would increase, as well as when additional stormwater runoff would arise from the development of housing for 7,000 households, with a planned population of 22,400 (**figure A9.3**). A railway station was also opened in 2008.

The reservoir's water depth is normally set at 1–1.5 m, and this can increase up to a maximum of 5 m in heavy rainfall events. According to the hydraulic design, the shoreline of the reservoir and pedestrian walkways along the waterways are intended to flood; however, adjacent residential neighborhoods are not affected by the increase in water volume.

Key Features

- **Sharing of costs of reservoir construction:** As a joint venture to carry out both urban development and flood management, strategic roles and cost-sharing arrangements were made among UR, MLIT, and Saitama Prefecture. UR, as the developer, was made responsible for (i) land acquisition, (ii) management of any additional stormwater runoff arising from the new development, and (iii) construction and O&M of the new development site. MLIT and Saitama Prefecture, as the river authorities, became responsible for (i) land acquisition, (ii) management of river floods, and (iii) construction and O&M of the flood management facility. By combining the two initiatives, costs and responsibilities were shared, thus reducing the burden borne by individual stakeholders (UR 2018). MLIT and Saitama Prefecture, for example, proposed that UR handle excessive stormwater runoff from the new development, as well as water outside the development site that could cause river overflow. In return, MLIT and Saitama Prefecture would jointly bear the cost of reservoir installation, while UR led the construction of the larger-capacity reservoir. O&M responsibilities were also shared among the three parties. As a result, the developer (UR) bore 44 percent of the entire cost, while the two river administrators owed 28 percent each (UR 2018; **table A9.1**). Similar arrangements were made for land acquisition, with the project benefiting from public land readjustment measures by which private landowners provided parts of their land free for public use; this also reduced the overall project cost, as compared with implementing it as a private project. For UR, the partnership was beneficial, as it was able to ensure its newly developed site had lower flood risks, and its development project was environmentally friendly and livable.

- **Engagement of the developer in constructing and managing public facilities:** In general, a large-scale land readjustment initiative involves realignment of a great many public facilities, such as roads, parks, sewers, and rivers. In such cases, local governments face issues in terms of human and financial resources to deal with land acquisition, relocation, and so on. For the Koshigaya Lake Town development, a direct implementation system was used, in which UR, as the developer, led the redevelopment of public facilities, including the planning and construction of the public flood management facility (reservoir), with proper review and approval carried out by the government (UR 2007).

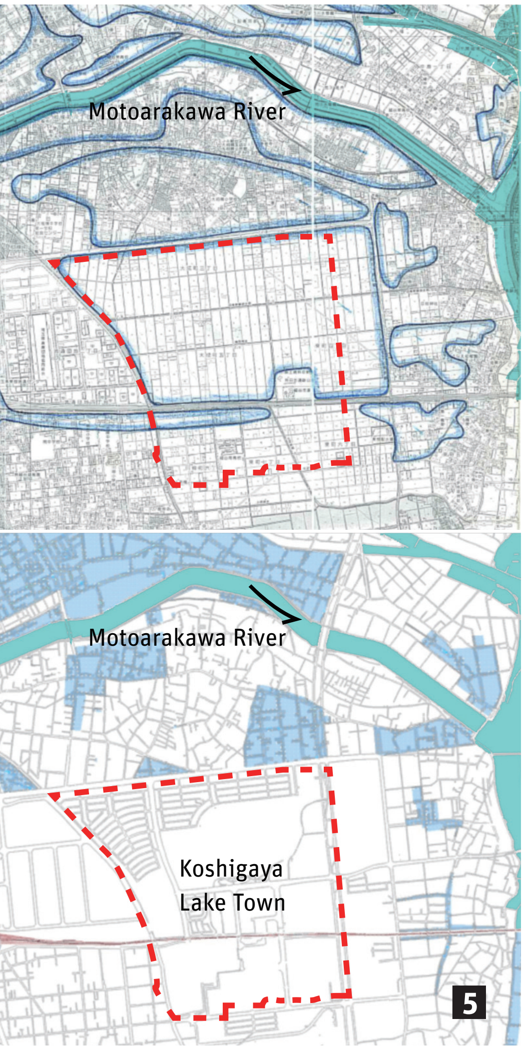
Results: Effective and Multipurpose Flood Management Investment through Joint Management

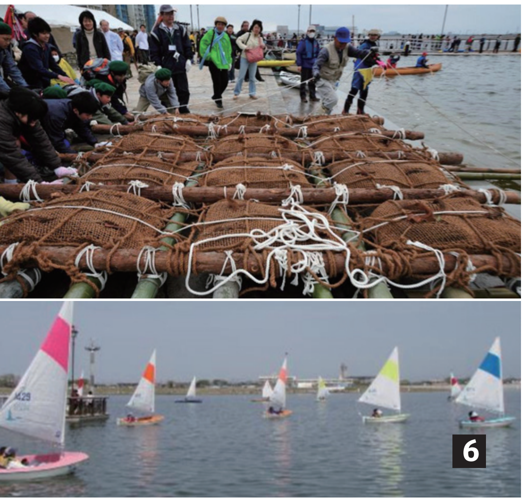
The collaboration among the public river administrators (MLIT and Saitama Prefecture) and the housing developer (UR) resulted in the development of one large reservoir facility to manage both river overflow and the additional stormwater generated by the development. Construction of large-scale aboveground flood management facilities can be extremely costly if done in isolation. This partnership arrangement to build a multipurpose flood management facility produced cost savings not only for construction but also for O&M by enabling cost and role sharing among the various parties involved.

The impact brought to the area by the establishment of this facility was significant. In 2015, when Typhoon Etau caused flood damage in the upper stream of the Motoarakawa River, the downstream area, including Koshigaya Lake Town, suffered no damage. A comparison with a 1991 event with equivalent rainfall intensity (shown in **figure A9.5**) demonstrates the impressive flood management achieved by the building of the reservoir (Koshiyaga City 2015a).

The success of the large-scale new urban development initiative at Koshigaya Lake Town was also owing to the strong collaboration among the public sector, the housing developer, and the community. The "Koshigaya Lake Town Hometown Project," launched in 2007, organized various recreational events, disaster prevention drills, and voluntary activities using the park spaces and reservoirs (**figure A9.6**). The events successfully involved commercial providers, local governments, and resident associations in promoting the life of Koshigaya Lake Town. In 2014, the project became a nonprofit organization under the same name (UR 2009, 2018). With the community's participation and enthusiasm, a high-quality, safe, and attractive living environment was generated.

Figure A9.4: The Lake Town Development: Shopping Mall and Residential Buildings
Photo Credit: Kenya Endo.





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	General Rule	Lake Town Rule
Runoff increase ..... A	Developer	Developer National government Local government
Flooding volume in the site ..... B		
Flooding volume outside of the site C		
Developer's share	(A+B)/(A+B)	(A+B)/(2A+2B+C)
River administrator's share	-	(A+B+C)/(2A+2B+C)
Basis of the concept	-Developments increase runoff and decrease water retention volume	-River administrators responsible to (A+B+C) -Developer responsible to (A+B)

1

Table A9.1: Mechanisms for Sharing the Costs and Responsibilities of Flood Management in Koshigaya Lake Town

Source: Yoshimura 2016.

Figure A9.5: Flooded Areas in 1991 and 2015

Source: Koshigaya City 2015a.
Note: Areas inundated by Typhoon No. 18 (1991) and Typhoon No. 18 (2015) are highlighted in blue.

Figure A9.6: Activities at Koshigaya Lake Town

Source: Yoshimura 2016.

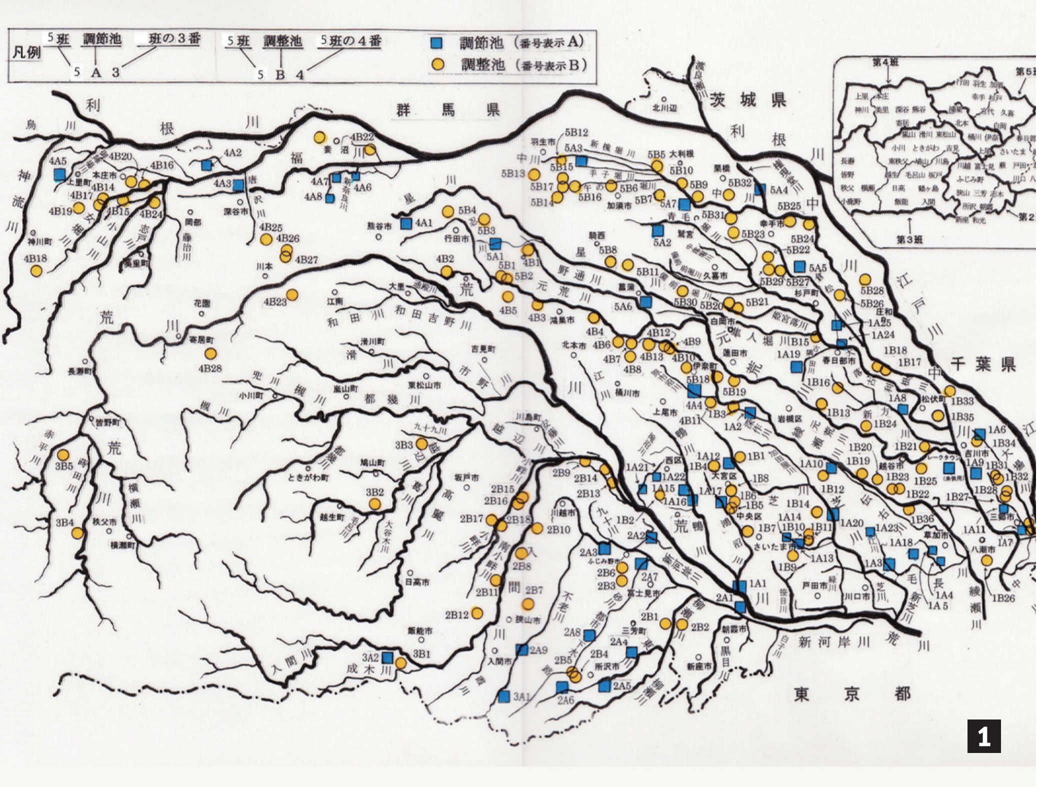

Figure A10.1: Schematic Illustration of Saitama Prefecture's Rivers, Detention Ponds, and Reservoirs

Source: Sainokawa Research Institute 2014.

Case 10: Reducing Surface Water and River Flood Risk by Implementing Reservoirs, Detention Ponds, and Parks: Saitama Prefecture

Location:	Saitama Prefecture
Site characteristics:	Saitama Prefecture, the fifth-largest prefecture in Japan by population (7.3 million), is located north of Tokyo. It has many major urban centers, including Saitama City (population 1.3 million) and Kawagoe City (350,000). The cities in Saitama Prefecture have high concentrations of population and assets, and remaining lands are mostly agricultural or hilly woodlands. Most of the rivers in Saitama Prefecture flow into Tokyo.
Flood management measure(s):	
Flood type	Surface water, river
Management capacity	For surface water flood management: Policy requires any urban development more than 1 ha in area to have a stormwater runoff management facility (ranging from 500 m^3/ha to 1,200 m^3/ha).[a]
	For river flood management: Combined storage capacity of all large-scale reservoirs, detention ponds, and parks exceeds 10.3 million m^3 in Saitama Prefecture.[a]
Type of measure(s)	Structural (gray and green)
	Reservoirs, detention ponds, and parks
	Nonstructural (policy)
Relevant entities:	
Implementation:	Large rivers: Mainly MLIT in collaboration with local governments
	Small and medium-sized rivers: Mainly local Saitama Prefecture authorities
	Watershed management: Private developers, property owners
O&M	Typically same as above
Finance	Typically same as above
Construction period:	Not applicable
Cost:	Saitama Prefecture's budget for Japanese FY2018 for flood management measures for concentrated and extreme rain, including investments for reservoirs, detention ponds, and parks, was reported as approximately ¥11.4 billion ($103 million).[b]
Additional benefits and functions:	Increase in public recreational spaces
	Environmental conservation and sustainability
	Urban (re)development
Sources:	Saitama Prefecture 2018b, except where otherwise noted.
	a Saitama Prefecture 2017.
	b Saitama Prefecture 2018a.

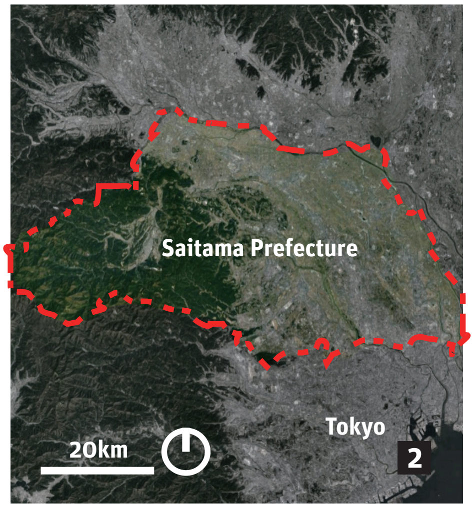

Figure A10.2: Site Context
Source: Google Earth. *Note*: km = kilometer.

Context: Flood Risk and Rapid Urbanization

The rapid economic growth that took place in Japan from 1955 led to the rapid urbanization of Tokyo's northern neighbor, **Saitama Prefecture**, beginning in the 1970s. To handle the resulting urban stormwater, most rivers in the prefecture, which were originally used for agricultural irrigation, were repurposed into drainage channels. This increased drainage demands for large rivers, such as the Tone and Arakawa rivers, as well as for most small and medium-sized rivers running throughout Saitama Prefecture, which did not have sufficient conveyance capacity to address the increased runoff. Although authorities initially planned to expand the rivers' conveyance capacity by widening them, this was difficult to do in Saitama Prefecture because most rivers flowed to downstream Tokyo, where limited land and its high costs made any further widening of the rivers impossible. In light of this situation, Saitama Prefecture's strategy for urban flood risk management involved taking (i) an integrated approach that combined river and rainwater management interventions with the participation of various stakeholders, including national and local governments and private developers, and (ii) a decentralized approach, implementing various types of interventions (in terms of size and function, such as reservoirs, detention ponds and parks, and so on). In this way, management of flood risks could be both centralized, by channeling stormwater generated in various locations to one consolidated site, and decentralized, by implementing smaller interventions in many places, normally near the locations where stormwater drainage needs would arise.

Solution: Investment Design and Key Features

Investment Design

By 2014, through Saitama Prefecture's integrated urban flood risk management (IUFRM) approach, more than 170 detention facilities with a capacity of over 10,000 m^3 had been installed in the prefecture through both private and public efforts. Of these, 51 were for the purpose of detaining water to avoid overflow into rivers, and 119 were to manage additional stormwater drainage from new developments (Saitama Prefecture 2018b).

Key Features

- **Integration of diverse approaches to flood risk management:** The 170 interventions implemented in Saitama Prefecture were diverse in type, size, and approach and included very large-scale interventions led by MLIT, such as the Watarase Reservoir, with detention capacity up to 26 million m^3 over an area of 4.5 km^2. Detention facilities whose development was led by Saitama Prefecture included multipurpose detention parks, which also served as public parks and athletic fields, with capacities ranging from 132,000 m^3 to 891,000 m^3; underground facilities with capacity around 10,000 m^3; and detention ponds and parks around rivers with capacities ranging from 1.1 million to 36 million m^3. City-led detention facilities were also often developed using a multistakeholder, multipurpose approach; examples included joint implementation with private housing developers. The management capacities of these facilities are normally under 100,000 m^3, with some facilities as large as 190,000 m^3 (Saitama Prefecture 2018b).

- **Engagement of private sector in sharing roles, costs, and responsibilities for flood management through policy instruments:** Additionally, Saitama Prefecture took a progressive approach by mandating that all new private development projects (commercial, residential, and so on) with an area of more than 1 ha install detention facilities. This approach built on the administrative *guidance* first released by the prefecture in 1968 under the national Urban Planning Act, which was then further advanced as a *requirement* under the ordinance enacted in 2006 (Saitama Prefecture 2018b).
- **Catalyzing of partnerships across sectors to establish multipurpose investments:** Many multifunction and multipurpose interventions, for both flood and non-flood times, emerged from a prefecture-wide effort to engage various sectors and stakeholders in the development of the flood management facilities. Many detention park and reservoir functions, for example, were utilized for agricultural lands, public recreational spaces, schoolyards and athletic fields, or natural biodiversity habitats. Many were developed with quasi-public and private green spaces adjacent to, or part of, new large housing developments by public and private developers. New shopping centers with lots of green, public amenities were also constructed. Thus, the flood management investments could deliver various additional benefits by increasing public amenities and livability, environmental conservation and sustainability, and economic development through the establishment of new or renovated housing and commercial developments.

Figure A10.3: Oyoshi, Yanagishima, and Yatsuka Detention Facilities in Saitama Prefecture
Source: Saitama Prefecture 2019.

Results: Multiple Stakeholders Sharing Roles, Costs, and Responsibility

The efforts led by the Saitama Prefecture's government illustrate how the public sector can promote flood management measures comprehensively in a region by implementing policy that makes them a requirement of urban development and by bringing together various stakeholders to share roles, costs, and responsibilities. This top-down policy-based approach, combined with a bottom-up approach that has enabled a variety of unique site-level interventions throughout the prefecture, has provided many examples of the diverse ways in which roles and responsibilities can be shared across stakeholders by incorporating various purposes and benefits besides flood management into interventions.

As a result, Saitama Prefecture has been able to implement an IUFRM approach on a large, prefecture-wide scale. Through close monitoring of the impact of its river and surface water flood management investments throughout the prefecture, Saitama has also been able to assess carefully the damage from flood events before and after interventions and has found significant reductions in the numbers of households and buildings inundated through several heavy rain events. During Typhoon Ma-on (No. 22) in 2004, for example, the storage of 5.4 million m^3 of stormwater in the prefecture's 21 large detention basins effectively prevented serious flood damage to downstream areas (Saitama Prefecture 2017).

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Case 11: Reducing Surface Water Flood Risk by Enhancing a Sewerage Detention Facility in Collaboration with the Private Sector: **Shibaura Wastewater Treatment Facility**

Location:	Shinagawa Station, Minato Ward, Tokyo
Site characteristics:	Central business district, within a 10-minute walk of a large rail transportation hub, Shinagawa Station
Flood management measure(s):	
Flood type	Surface water
Management capacity	Maximum storage capacity of 76,000 m^3 of unprocessed stormwater and wastewater[a]
Type of measure(s)	Structural (gray)
	Sewerage management facility improvement with involvement of private sector
Relevant entities:	
Implementation	Underground combined sewer and stormwater detention facility: Bureau of Sewerage, TMG with technical and financial support from MLIT; construction by NTT Urban Development (bid winner)
	Urban redevelopment of 11,000 m^2 area above sewerage facility (30-year lease): Bureau of Urban Development, TMG with a group of private developers, including project owners—NTT Urban Development (NTT UD), Taisei Corporation, Hulic Co. Ltd., and Tokyo City Development Co. Ltd.; project designers—NTT Facilities, NTT UD, Taisei Corporation, and Nihon Suiko Sekkei Co. Ltd.; and, for construction—Taisei Corporation
O&M	NTT UD, Taisei Corporation, Hulic Co. Ltd., Tokyo City Development Co. Ltd., and Bureau of Sewerage, TMG
Finance	Underground combined sewer and stormwater detention facility—TMG Lease of aboveground land for 30 years—NTT UD
	Urban redevelopment of commercial building (Shinagawa Season Terrace) and park (Shibaura Chuo Park)—NTT UD, Taisei Corporation, Hulic Co., Ltd., and Tokyo City Development Co., Ltd.
Construction period:	2012–15[b]
Cost:	Construction of underground combined sewerage and stormwater detention facility: costs borne by TMG amount to ¥1.1 billion ($10 million) and by NTT UD, ¥7.7 billion ($70 million)
	Lease of aboveground land for 30 years: ¥86.4 billion ($785 million) (bid price by NTT UD)
	Construction of artificial ground above existing water treatment facility and park development: ¥780 million ($7.1 million) (borne by TMG)
	Aboveground construction cost: not available[c]
Additional benefits and functions:	Urban redevelopment
	Environmental benefits: prevention of untreated water overflow into river and sea, heat island mitigation, attraction of urban fauna and flora
	Tenancy fee income to TMG
Sources:	Bureau of Sewerage, TMG (n.d.), except where otherwise noted.
	a TMG n.d.
	b Taisei Corporation 2012.
	c All costs from Hashimoto (2015).

Figure A11.1: Overall View of the Site

Source: Bureau of Sewerage, TMG n.d.

Figure A11.2: Site Context

Source: Google Earth. *Note*: m = meter.

Context: Urban Development and Environmental Impacts from Floods

The Shibaura Wastewater Treatment Facility has been responsible for sewerage water treatment in Tokyo, including for the **Chiyoda, Chuo, and Minato wards**, since 1931. Beginning in 2012, renovation of the aging facility was undertaken in stages, with two objectives: (i) to mitigate the postflood environmental impact of the combined sewerage and drainage system, and (ii) to utilize the land where the facility is located, and effectively capture its high value.[17]

Combined sewerage and drainage system and its environmental impact

Because land is scarce in Tokyo, 82 percent of the city's wards historically have adopted a single conveyance channel for both sewerage and rainwater (Bureau of Sewerage, TMG 2015). When heavy rainfall exceeds the capacity of the wastewater treatment facilities, mixed sewer and stormwater overflows into rivers and the sea without proper treatment. The resulting water pollution and eutrophication can have a significant environmental impact (TMG 2017).

Capturing and utilizing high-value land

The Shibaura Wastewater Treatment Facility is located in Konan District, Minato Ward, a 10-minute walk from Shinagawa Station. The estimated value of the land near the station is four times the average in the Tokyo Metropolitan Area,[18] and, as it is host to a central station for the Linear Central Shinkansen (high-speed rail) and close to Haneda International Airport, the land value of the area is expected to continue to rise as its importance as a major transportation hub increases (Hashimoto 2015).

Establishing an urban identity as an environmentally friendly city

Under the district guidelines for community development around Shinagawa Station and Tamachi Station, formulated in 2007, a key priority under the MLIT-led initiative implemented in partnership with TMG was to develop a model for an environmentally friendly city. Water recycling and access (through the development of public parks, corridors, amenities integrating water design, and so on) were highlighted as key actions for implementation (TMG 2017). Accordingly, enhancing the environmental performance and value of the sewerage management plant as well as the surrounding area became an important agenda item within the redevelopment process.

Solution: Investment Design and Key Features

Investment Design

The renovation of the Shibaura Wastewater Treatment Facility was implemented in

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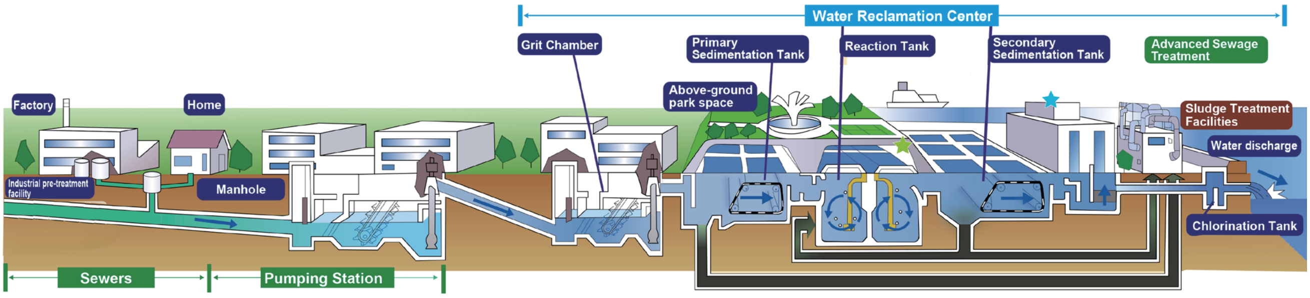
17 "Land value capture" is an approach to development that enables communities and/or governments to recover and reinvest increases in land value that result from public investment and other government actions. Also known as "value sharing," land value capture is rooted in the notion that public action should generate public benefit.

18 The average land price in 2019 was ¥1,096,445/m^2 (\$9,968/m^2), while the value in the area near Shinagawa Station was ¥4,494,000/m^2 (\$40,855/m^2), based on MLIT's land price publication; see http://www.land.mlit.go.jp/landPrice/AriaServlet?MOD=2&TYP=0).



conjunction with a large-scale, multi-stakeholder, urban redevelopment initiative that started in 2012. TMG, the owner of the 11,000 m^2 area occupied in large part by the Shibaura Wastewater Treatment Facility, tendered for a private sector firm that would redevelop the area under a 30-year lease agreement, as well as renovate the plant, and construct a combined sewerage and stormwater detention facility with a capacity of 76,000 m^3 underneath the developed land.[19]

In 2009, a consortium of private developers bid ¥7.7 billion ($70 million) for the construction of the underground detention facility and ¥86.4 billion ($785 million) for the lease for development. On the leased land, a 32-story commercial and office building (Shinagawa Season Terrace), as well as a publicly accessible park were developed. TMG is recovering the lease fee through a land-value capture mechanism, whereby the income generated through maintaining ownership and leasing 60 percent of the newly constructed building is retained by TMG. The generated income is utilized by TMG for O&M of the sewerage facility.

Shinagawa Season Terrace includes various innovative features, such as disaster resilience (with top-level seismic standard and resilience features so the building can serve as an evacuation hub in case of emergency), energy efficiency, water recycling, and an ecosystem-based design (Shinagawa Season Terrace n.d.).

Key Features

- **Utilization of new regulatory tools to enable multibenefit urban development:** According to the City Planning Act in Japan, development is highly restricted in areas where public urban facilities, such as roads, rivers, parks, and sewer pipes, are located (Real Estate Research Institute, Inc., n.d.). This has made integrating office building development with the renovation of the Shibaura Wastewater Treatment Facility challenging. The issue was solved by utilizing the new legislative concept called "vertical urban planning," which allows stakeholders to undertake redevelopment projects at multiple levels, regardless of overlapping public urban facilities beneath or above them. This project became the first wastewater treatment facility in Japan that applied the Multi-Level City Planning System under the City Planning Act (Bureau of Sewerage, TMG n.d.), providing a legal basis for this new multi-stakeholder and multipurpose redevelopment approach. The development proposal was divided in two main projects: (i) the underground public wastewater and stormwater treatment and detention facility; and (ii) the aboveground private sector–led commercial redevelopment. The proposals were reviewed jointly by TMG's Urban Planning Council and approved on three bases: (i) the need for renewal of the treatment facility; (ii) a request from neighboring community members for more public park spaces; and (iii) upcoming large-scale redevelopment projects around Shinagawa and Tamachi stations,

19 During heavy rain events, the detention facility holds the combined wastewater and stormwater to avoid releasing large volumes of untreated water into the nearby canal. Once a storm passes, the detained water is first treated at the wastewater facility and then released. However, during extreme heavy rain events, the combined wastewater and stormwater are released directly. The first flush at the beginning of a heavy rain event tends to have a higher concentration of sewerage compared to the flushes released at later stages. Thus, it is retained whenever possible.

Figure A11.3: Conceptual Diagram of the Shibaura Wastewater Treatment Facility

Source: Information provided by the Bureau of Sewerage, TMG.

Figure A11.4: Treatment Plant Interior and Facility Integrated with Decked Landscape Above

Photo Credit: Kenya Endo.

including the new high-speed rail development.

- **Financing of construction and O&M of flood management facilities through public-private partnership initiatives:** TMG collaborated with MLIT as well as a consortium of private sector firms to establish additional underground flood management capacity as part of a larger urban redevelopment project. This collaboration enabled TMG to share the expense of constructing an expensive underground facility, limiting its financial burden. Additionally, the annual income to TMG derived from adoption of a land-value capture and lease approach has defrayed the expense of O&M for the flood management facility, thus lowering its life-cycle cost. The engagement of the private sector to co-finance a flood management facility may be a cost-effective approach for constructing such facilities in other areas with high land values, such as Shinagawa.
- **Enhancement of environmental sustainability through flood management:** MLIT's and TMG's strong support for enhancing the sewerage management facility by establishing a new stormwater detention facility derived from the high priority they place on advancing the Shinagawa-Tamachi area as an environmentally friendly model city. Flood management and environmental sustainability investments are often mutually reinforcing, as avoiding storm and sewerage water overflow from floods can reduce risks not only of inundation but also of water pollution. Additionally, enhancing green space and biodiversity in the area can have the flood management benefits of increasing infiltration capacity and reducing inundation. Flood management and environmental sustainability also share common monitoring and evaluation processes to assess the impact of and benefits from investments, such as monitoring of water quality, odor, and other shared parameters (Tabuchi 2011).

Figure A11.5: Public Greenery above the Treatment Facility
Photo Credit: Kenya Endo.

Results: Multiple Benefits through Cost and Role Sharing with the Private Sector

TMG's efforts to engage the private sector consortium actively in the design and construction of the underground storm and sewerage water detention facility, as well as the aboveground urban redevelopment, enabled the creation of a cohesive, multipurpose, and attractive urban space, which would have been extremely difficult if these elements had been implemented by the public or private sector alone. In addition to its public benefits, such as flood management and environmental sustainability, the project resulted in the building of attractive commercial and office space, used by premier businesses and firms, and received recognition for its innovative green and resilient design.

This case illustrates how important it is for city governments to (i) plan and coordinate efforts proactively to utilize new legal systems and urban planning tools to make a project valuable and accessible to various stakeholders; (ii) explore ways in which flood management investments can be integrated within other key priorities and projects related to urban development and environmental sustainability promoted by various stakeholders, including the national government and the private sector; and (iii) consider creative ways to share roles and establish ownership, financing, and management responsibilities among a range of stakeholders.

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Case 12: Reducing Surface Water Flood Risk through Community-Based Rainwater Harvesting Systems: **Sumida Ward, Tokyo**

Location:	Sumida Ward, Tokyo
Site characteristics:	Sumida Ward is located in Eastern Tokyo. Most of its land is below sea level, with a high concentration of residential and commercial buildings. It is one of the most flood-prone areas within the Tokyo Metropolitan Area.
Flood management measure(s):	
Flood type	Surface water
Management capacity	Public rainwater harvesting system (RHS): 41 facilities; total storage volume—9,374 m^3; total collection area—62,462 m^2
	Private RHS—290 facilities; total storage volume—14,292 m^3; total collection area—145,032 m^2
	Community RHS (Rojison): 21 facilities; total storage volume—283 m^3
	Household RHS: Approximately 293 facilities; total storage volume—61 m^3 small tanks installed with subsidy program from Sumida Ward[a]
Type of measure(s)	Structural (gray)—including public, private, community, and household rainwater harvesting system (roof and underground/aboveground tanks and recycling system)
Relevant entities:	
Implementation	Public rainwater system (RS): Sumida Ward and TMG
	Private RS: Private facility owners
	Community RS: Community groups and nonprofit organizations
	Household RS: Homeowners/citizens
O&M	Same as above
Finance	Same as above, but with subsidies from Sumida Ward
Construction period:	Not applicable
Cost:	Community RS/Rojison (including water tank and hand pump): ¥2 million–¥9 million ($18,100–$81,800)/unit[a]
	Rainwater tank: Up to ¥100,000 ($900)[b] for 200-liter capacity of a household type, including installation cost
Additional benefits and functions:	Community revitalization
	Water recycling and drought management
	Increase in public awareness of disaster preparedness
Sources:	Sumida Ward 2018b, except where otherwise noted.
	a Sumida Ward 2008.
	b Rainwater Tank Consultation Room n.d.

Context: Urban Development and Flood Risks

Sumida Ward's location on low-lying land near the Sumida River exposes its high concentration of houses and office buildings to high flood risks. During the 1980s, urban flooding frequently occurred in the ward during heavy rains as low infiltration and drainage capacity resulted in inundated streets and buildings. At that time, impervious surfaces covered over 50 percent of Tokyo's 23 wards, while the rate for Sumida Ward was over 70 percent (Next Wisdom Foundation 2015). Additionally, enhancing Sumida Ward's infiltration capacity underground was difficult, given that most of its land is below sea level. With limited space to develop new, large-scale stormwater detention facilities aboveground, the ward relied heavily on publicly financed and developed high-cost gray infrastructure, such as underground drainage channels and detention facilities and pumps. Increasing flood risks and additional developments, however, created an urgent need to take further measures against surface water flooding in the area.

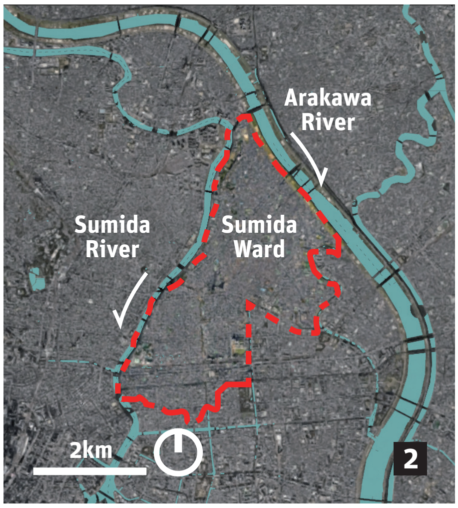

Figure A12.1: Image of Rojison (Community-Based Rainwater Utilization System)
Photo Credit: People for Rainwater (NPO).
Figure A12.2: Site Context
Source: Google Earth. *Note*: km = kilometer.
Figure A12.3: Sumo Wrestling Arena
Source: Sumida Ward 2016.

Solution: Investment Design and Key Features

Investment Design

To reduce increasing risks and damage from surface water flooding, Sumida Ward began a movement in 1982 to harvest, store, and utilize rainwater through public, private, and community efforts, based on the concept of an "urban dam." The collaboration enabled the installation of rainwater storage facilities in residential areas and public and private facilities distributed widely throughout the ward, providing a decentralized approach to surface flood management.

Sumida Ward installed rainwater systems in public buildings, each normally comprising a collection roof, an underground storage tank, and a recycling system to provide water for flushing toilets, watering plants, and similar uses. The ward also established a subsidy program in 1995, providing financial and technical support to encourage the installation of large, medium, and small tanks by the private sector, community groups, and households. The subsidy program is detailed in **table A12.1**.

One of the first installations of such a facility through this initiative was at the Sumo Wrestling Arena (**figure A12.3**), where the private Japan Sumo Wrestling Association constructed a 1,000-ton capacity rainwater storage tank in 1984. Since then, Sumida Ward has been promoting the installation of stormwater storage facilities in public buildings, community facilities, and residential areas to reduce flood risk, as well as to encourage the use of rainwater for toilet flushing and the irrigation of gardens and roadside greenery.

The "Rojison," a community-based rainwater utilization system, began operation in 1988 (**figures A12.4** and **A12.5**). A Rojison is an underground, community-owned, rainwater detention facility whose main function is to store rainwater for urban flood management and reuse the stored water for emergency situations; it is now at 21 locations throughout the ward. A Rojison collects rainwater from the roofs of residential buildings and stores it in its underground tank. Using a hand pump, citizens can withdraw the stored water to water gardens and wash roads, while Rojisons contribute to the ward's flood risk management measures.

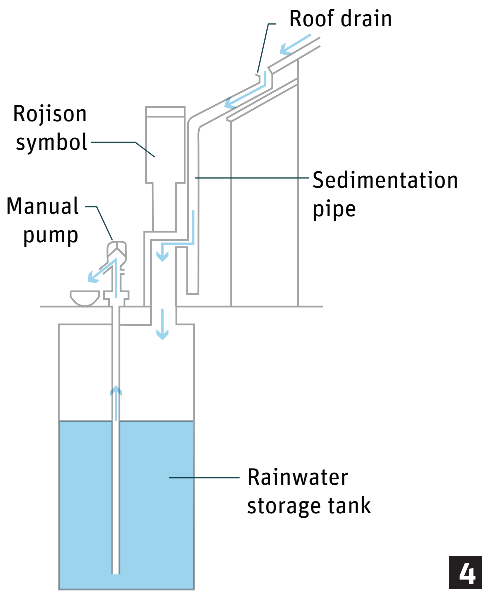

Figure A12.4: Sectional Diagram of a Rojison

Source: Modified based on information from Sumida Ward (2013).

Figure A12.5: Community Members Using Water from a Rojison

Photo Credit: People for Rainwater (NPO).

Key Features

- **Wardwide movement prompted by strong commitment and leadership of Sumida Ward staff:** The efforts of the staff of Sumida Ward in taking an alternative, community-based approach to flood risk management were instrumental in spurring the citywide efforts that have continued over the past three decades. In the early 1980s, the Sumida Ward staff and mayor, in light of the construction of the new Japan Sumo Wrestling Arena, approached and convinced the Sumo Wrestling Association to integrate a rainwater storage tank, while sharing the city's vision to install similar rainwater systems in all new public buildings throughout Sumida Ward. Furthermore, Sumida Ward advocated, both locally and globally, for the importance and significance of rainwater harvesting by hosting the Tokyo International Conference on Rainwater Utilization in 1994, initiating a subsidy program in 1995, establishing a Rainwater Utilization Ordinance in 2008 (Ministry of Internal Affairs and Communications 2015), and issuing the Sumida River Environment Declaration, which promotes rainwater utilization, in 2009. All of these efforts were also instrumental in raising the awareness of and support from residents and the private sector.
- **Community-based approach to rainwater system installation and O&M:** Civil society has also played a significant role in the implementation, scaling, and O&M of rainwater systems in Sumida Ward. After the 1994 international conference, a nonprofit organization, the Citizens Group to Promote Rainwater Utilization, was established, with the aim of supporting and promoting a bottom-up approach to rainwater storage and utilization. In addition to informing households and community groups about the ward's subsidy program and helping them get access to it, the organization provides information and technical support for O&M with other nonprofit organizations, such as People for Rainwater (Sumida Ward 2018b). Through this community-based approach, O&M for rainwater systems located in different places throughout Sumida Ward is led by residents who live near the facilities and conducted in cooperation with community groups, nonprofit organizations, and the ward (Next Wisdom Foundation 2015). Furthermore, in partnership with nonprofit organizations,[20] the government has promoted the technological development of water quality testing, water quality improvement, rainwater utilization, and rainwater storage and infiltration to extend these efforts throughout the ward, to the Tokyo Metropolitan Area, and to other urban areas in Japan.

Results: Widespread Implementation and O&M of Rainwater Management Systems through a Participatory and Multihazard Approach

While the rainwater harvesting capacity of each household may be small, the total contribution from household rainwater harvesting and storage systems toward reducing stormwater runoff becomes significant through a collective wardwide effort. In 2008, 21 Rojisons were installed in Sumida Ward (Sumida Ward 2018a);

20 See, for example, People for Rainwater (http://www.skywater.jp/aboutus#shiminnokai) and Rain City Support (https://amemachi.org/).

Tank Type	Description	Subsidy Amount	Maximum
Underground Storage Tank	The underground pit is used as a rainwater storage tank for large buildings, condominiums, etc. Stored water is used mainly for washing, toilets, and watering plants.	Subsidy amount per 1 m^3: ¥40,000 (US$363) times effective storage capacity (m^3)	Up to ¥1 million (US$90,909)
Mid-Size Storage Tank	Tank with storage capacity of 1 m^3 or more. Stored water is used mainly for washing, toilets, and watering plants.	Tanks made of fiber-reinforced plastic (FRP), stainless steel, or concrete: subsidy amount per cubic meter ¥120,000 (US$1,090) times effective storage capacity (m^3) Tanks made of high-density polyethylene: subsidy amount per cubic meter ¥45,000 (US$409) times effective storage capacity (m^3)	Up to ¥300,000 (US$2,727)
Small Storage Tank	Tank with storage capacity less than 1 m^3. Stored water is used mainly for watering plants.	50 percent of rainwater tank, including cost of construction.	Up to ¥40,000 (US$363)

Table A12.1: Types of Tanks and Subsidies

Source: Sumida Ward 2018a. *Note*: m^3 = cubic meter.

by March 2018, there were 645 facilities with a capacity of 24,010 m^3, equivalent to approximately 90 liters of rainwater per ward resident (Sumida Ward 2018b). Local residents and communities lead O&M of the rainwater harvesting and storage systems installed at the community level (Rojison), in their businesses, and in households. The community storage facility is often seen as a water resource by the surrounding residents and is often used for watering plants, gardens, and urban farms, in addition to serving an important role during times of disaster as a backup water supply and for firefighting, while the collective management of this community asset helps raise awareness and knowledge of local flood risks.[21] The firefighting benefits are particularly important for the neighborhoods in Sumida Ward, given its long history of managing fire risks. With their strong linkage to the community's needs and sociocultural context for disaster and water resource management, the efforts of Sumida Ward illustrate how initiatives in flood risk management led by residents and communities (including both implementation and O&M) can be supported and enhanced through various mechanisms and partnerships with the local government, including technical support, policy, and subsidies; the promotion of partnerships with the private sector; and so on.

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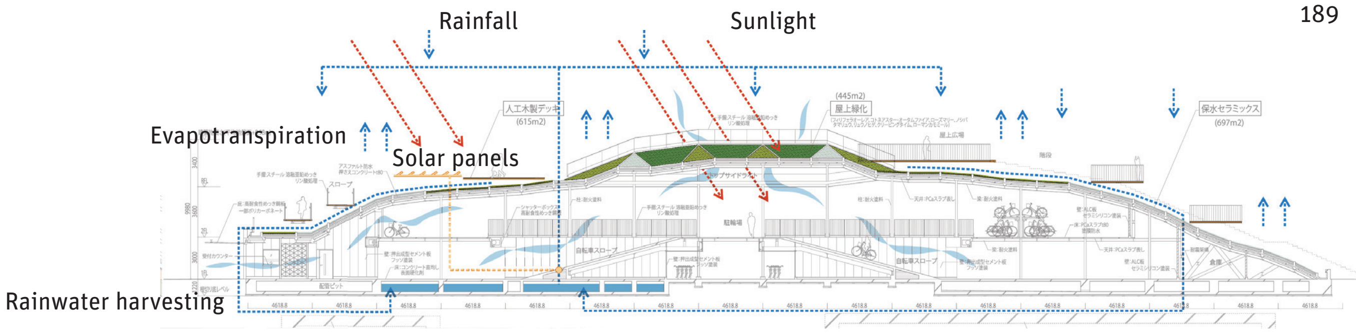
21 The stored water in the rainwater storage tanks needs to be drained before heavy rains to provide storage capacity.

Case 13: Reducing Surface Water Flood Risk by Implementing a Rainwater Harvesting Tank in a Private Urban Development: Tokyo Skytree Town

Location:	Tokyo Skytree Town, located in Sumida Ward between the Arakawa and Sumida rivers, Tokyo
Site characteristics:	The new redeveloped town includes the world's highest radiowave tower along with office, commercial, and recreational facilities, with a total site area of approximately 36,900 m^2. Much of Sumida Ward, which is located in Eastern Tokyo, is below sea level and contains a high concentration of residential and commercial buildings. It is one of the most flood-prone areas within the Tokyo Metropolitan Area.
Flood management measure(s):	
Flood type	Surface water
Management capacity	Rainwater harvesting tank capacity: 800 m^3
	Stormwater detention capacity: 1,830 m^3
Type of measure(s)	Structural (gray)
	Rainwater harvesting system (tank); underground stormwater management facility (cistern)
Relevant entities:	
Implementation	Tobu Railway Company, Tobu Tower Skytree Company
O&M	O&M: Same as above, with strong private sector contribution as part of corporate social responsibility
Finance	Same as above
Construction period:	2008–12
Cost:	Total development cost: ¥143 billion ($1.3 billion)
Additional benefits and functions:	Rainwater harvest and reuse
	Development with rich commercial facilities and thematic attractions that make it an attractive tourist destination
Sources:	Tsukahara 2012.

Context: Landmark Project in Area at High Risk for Flooding

With its low elevation and its location near the Sumida River, **Sumida Ward**, as described in **case 12**, is subject to high flood risks. The site where the Tokyo Skytree Town now stands was a large storage yard for Tobu Railway's freight trains until 1993. In 2006, the site was selected from among other candidates for development because of (i) the availability of extensive vacant land, (ii) consensus among local stakeholders, and (iii) proximity to other tourist destinations, such as Asakusa (Yamamoto 2012). The challenge was to incorporate rainwater and stormwater management schemes within the overall development site.



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Solution: Investment Design and Key Features

Investment Design

Tokyo Skytree Town was constructed together with a broadcast tower, 634 m in height. The development consists of a high-rise office building, a large shopping mall, and thematic attractions, including an aquarium and planetarium, among others. The site, which is adjacent to two train stations (Oshiage and Tokyo Skytree stations), attracted over 50 million visitors in the first year (Nihon Keizai Shinbun 2013). As part of the development, a large rainwater harvesting tank (capacity 800 m^3) and an underground stormwater detention cistern (capacity 1,835 m^3) were installed. The development of Tokyo Skytree Town was initiated by the privately owned Tobu Railway Company in 2008, with a high potential for generating economic benefits by attracting both local and international visitors, as well as new business opportunities, to the surrounding areas (Horie 2012).

Key Features

- **Private developer's strong incentive to implement and manage a rainwater harvesting tank as part of its corporate social responsibility (CSR):** Although Sumida Ward has a subsidy scheme for rainwater harvesting and reuse, the private developer chose not to apply for it and instead self-sponsored the installation cost as part of its CSR activities. O&M for the facilities is conducted by the private developer as well, as part of its CSR activities to support the ward's mission of promoting rainwater reuse. Most rainfall on-site is collected strategically from the roofs and guided to the harvesting tank through downpipes. The harvested water is reused to cool buildings and solar panels, irrigate rooftop gardens, and flush toilets. In this way, the rainwater harvesting system has the potential to reduce the rate of water consumption by as much as 45 percent, which is greatly beneficial to the developer.
- **Large underground cistern to cope with stormwater runoff from the area:** In addition to the rainwater harvesting tank, a large underground stormwater detention cistern was implemented, given the region's high flood risk. In determining the size of the cistern, the developer chose to adopt a larger management capacity based on two criteria: a target specified by TMG's Bureau of Sewerage and the size of the land readjustment project. Tokyo Skytree Town development has become a flagship project that strongly echoes the ward's effort toward rainwater reuse, as well as addressing the local area's high risk of flooding. The private developer's proactive engagement in stormwater runoff management, reuse, and O&M was greatly appreciated by Sumida Ward.

Results: Installation of Flood Management Facilities Driven by High Potential for Economic Benefits

The Tokyo Skytree development is unique for the strong initiative taken by its private developer, whose efforts were driven by the high landmark profile of the site and the project's great economic attractiveness. Since the tower, buildings, and infrastructure were developed simultaneously, planning and installing related water management facilities together with them was more cost-effective than retrofitting or adding to an existing development. The project was aligned

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Figure A13.1: Overall View of the Site

Photo Credit: Kenya Endo.

Figure A13.2: Site Context

Source: Google Earth. *Note*: m = meter.

Figure A13.3: Rainwater Harvesting Tank and Renewable Energy Features Installed at Parking Building for 2,600 Bicycles in Front of Oshiage Station

Source: Modified based on information from the Institute for Building Environment and Energy Conservation (2019).

Note: The bicycle parking facility was built right next to Oshiage Station, and the project was led and implemented by Sumida Ward. Although much smaller in scale (4,048 m^2), the building was developed based on the same principle as the Tokyo Skytree Town project for rainwater storage and reuse. The building has an underground rainwater harvesting tank that collects rainwater from the roof and reuses it for irrigation and toilet flushing. Between the storage tank and the porous ceramic surface and vegetation that cover 65 percent of the roof, 100 percent of the rainwater received is recirculated within the building.

Figure A13.4: Tokyo Skytree Town Shopping Mall (Soramachi) and Urban Surroundings

Photo Credit: Kenya Endo.

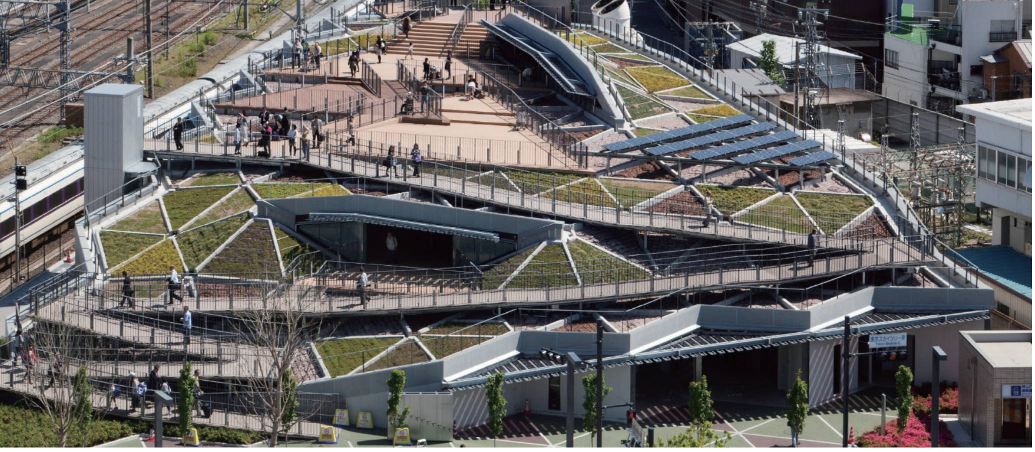

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Figure A13.5: Bicycle Parking Building
Source: Institute for Building Environment and Energy Conservation (2019).

with Sumida Ward's effort to promote rainwater storage and reuse, also taking into account the vulnerability of its geographical location to flood risk. The private developer's strong interest in CSR for implementation and O&M enabled Sumida Ward to achieve high flood management capacity within a very dense neighborhood.

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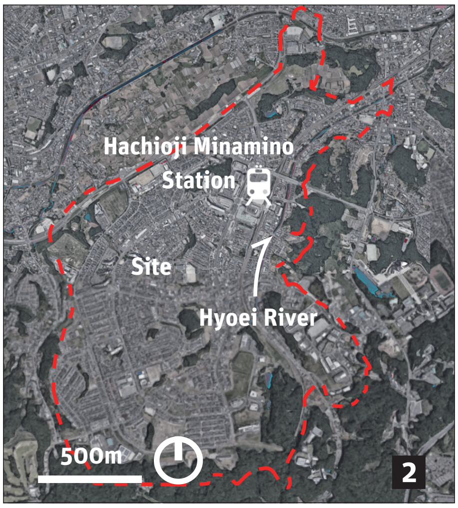
Case 14: Reducing Surface Water Flood Risk by Enhancing Pervious Surfaces and Detention Ponds in a New Town Development: **Hachioji Minamino City**

Location:	Hachioji Minamino District, Hachioji City, Tokyo, approximately 40 km west of the Tokyo city center
Site characteristics:	Residential area surrounded by low-density urban area and hilly woodlands
Flood management measure(s):	
Flood type	Surface water
Management capacity	Detention ponds (A and B): 126,000 m^3
	Infiltration system: Trench—7,753 m; pits—15,310 items; pervious pavers—163,387 m^2; gravel detention pools; above surface detention facilities—2,494 m^3 [a]
Type of measure(s)	Structural (green)
	Enhancing pervious surface
Relevant entities:	
Implementation	UR, Hachioji City/TMG
O&M	Same as above
Finance	Same as above
Construction period:	1986–97 (residents started to move in 1997)
Cost:	Total redevelopment cost (including flood management, urban development, and land readjustment projects): ¥256 billion ($2.3 billion)
Additional benefits and functions:	Urban development
	Environmental conservation
Sources:	UR 2009 and Suzuki 2014, except where otherwise noted.
	a UR n.d.



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Context: Rapid Urbanization and Flood Risks

On the heels of rapid economic growth that began in Japan in 1955, Tokyo's suburbs gradually began to feel the pressures of rapid population growth and urban sprawl. Hachioji City, 40 km west of Tokyo central, experienced unorganized suburbanization in areas mostly covered by secondary forests, among hills and small scattered communities with little road access or public transportation. In need of a new urban development framework, Hachioji City worked with UR to come up with the Basic Development Vision in 1980 for the development of **Hachioji Minamino City** (UR 2009). A key concern highlighted in this vision was the increase in flood risks from the neighboring Hyoei River, as well as ecological impacts to its riverine environment, as the proliferation of pavements and built-up areas from the new town development was expected to reduce substantially

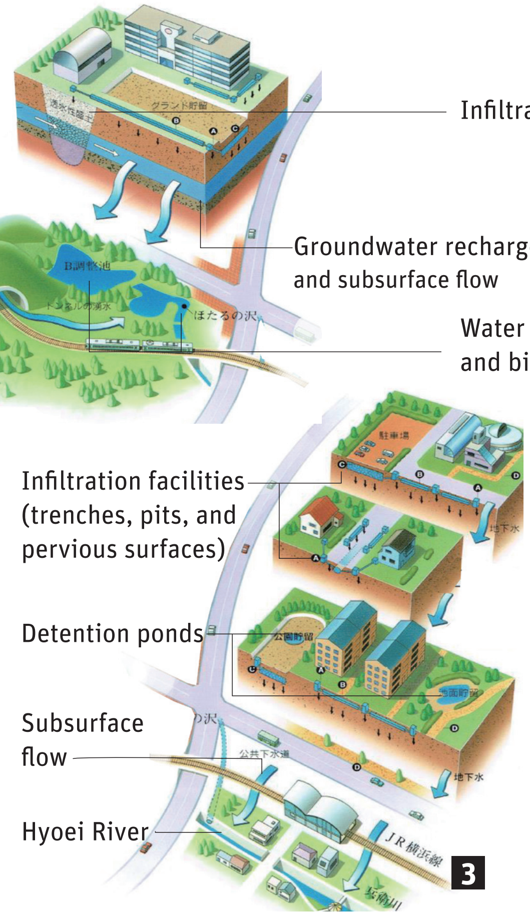

Figure A14.1: Overall View of the Site

Photo Credit: Kenya Endo.

Note: In the photo, the Hyoei River flows in front of the houses and the urban development is on the far side of it.

Figure A14.2: Site Context

Source: Google Earth. *Note*: m = meter.

Figure A14.3: Conceptual Diagram of the Infiltration System

Source: UR 2009.

Figure A14.4: Hachioji Minamino City before and after the Development

Source: UR 2009.

the amount of stormwater infiltration. For this reason, a water circulation and restoration system (some of whose basic principles are illustrated in **figure A14.3**) was incorporated into the development framework to mitigate the risks, preserve ecological values, and create a livable residential community.

Solution: Investment Design and Key Features

Investment Design

Hachioji Minamino City, a 394.3 ha new town development and land readjustment project carried out between 1986 and 1997, transformed a hilly forest area into a residential neighborhood of 28,000 residents. Given the urgent need to develop this residential area for its growing population, Hachioji City had asked UR to conduct a development feasibility study, to which UR had responded with the Basic Development Vision, and this was then approved as the South Hachioji City Land Readjustment Project in 1985 (UR 2009).

Key Features

- **Enhancement of environmental conservation:** As part of a water circulation and restoration system, the flood management intervention led to several environmental benefits. Among them were (i) the enhancement of groundwater recharge, as well as recharge of the Hyoei River, through infiltration (that is, through the installation of trenches, pits, and pervious surfaces); and (ii) the development of detention ponds, creating a new watershed that has enhanced habitats and biodiversity (Suzuki 2014). A technical panel comprising Hachioji City Government, TMG, and the Ministry of Construction (now MLIT), as well as representatives from academia and the community, provided significant design input and guidance to reduce the negative impact of the development and ensure environmental conservation (Suzuki 2014).
- **Raising of awareness and support through combining a large-scale flood management project with household initiatives:** In conjunction with the large-scale urban development project, homeowners who moved into Hachioji Minamino City were encouraged to install stormwater infiltration facilities in their homes, supported by subsidies from Hachioji City. The promotion was led by the Hachioji City government, which covers 90 percent of the installation cost (up to ¥270,000 or $2,454) for the infiltration facility for each household (Hachioji City 2018).
- **Monitoring of the effectiveness of flood management facilities:** To gain an understanding of the impact and effectiveness of the flood management investment, UR, in partnership with Hachioji City, monitored rainfall and the water storage volume of the system over 17 years from 1996 to 2013. Two major groups of parameters were observed: "wet season parameters" (runoff rate, seasonal variation, and maximum runoff volume) and "dry season parameters" (maintaining of Hyoei River base flow volume during drought season). The observations showed the installed systems were highly effective in minimizing stormwater runoff during the "wet season" and mitigating drought during the "dry season" (Suzuki 2014). During the observation period, the flow peak of the Hyoei River never exceeded the design maximum flow of 60 m^3/s in a 1-in-3-year rainfall and 85 m^3/s in a 1-in-70-year rainfall (Suzuki 2014).

Results: Disaster-Resilient and Environmentally Friendly City

With various stakeholders collaborating on the development of the new Hachioji Minamino City, the measures to manage the increased risks of surface water flooding were integrated smoothly and strategically into other public and private priorities, such as drought risk management, environmental sustainability, and the creation of attractive new residential properties. The oversight provided by a technical panel that included members of academia, also allowed for environmental and biodiversity considerations to be integrated into the design of the project. Additionally, linking to an ongoing rainwater infiltration promotion campaign for homeowners led by Hachioji City not only increased the overall flood risk management capacity of the newly developed urban area but also raised awareness and enhanced the knowledge of community members regarding the issue of flooding in the area, as well as various types of solutions that could be implemented at both the large scale and household level. This cultivation of community awareness and support, combined with annual monitoring of the flood management effects of the installed system, has ensured until today the sustainability and continuity of these efforts in Hachioji Minamino City.

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Case 15: Reducing Surface Water Flood Risk by Enhancing Pervious Surfaces: Grand Mall Park in Yokohama City

Location:	Grand Mall Park is located in Minato Mirai 21 (MM21) district, an urban development project in Yokohama City, Kanagawa Prefecture
Site characteristics:	MM21 district is developed on reclaimed land along Yokohama's waterfront. Various commercial facilities, high-rise office buildings, and tourist spots are placed around the harbor. Grand Mall Park, approximately 2.3 ha in size, is located in front of the Yokohama Museum of Art and includes the museum plaza.
Flood management measure(s):	
Flood type	Surface water
Management capacity	Rainwater retention capacity of single-sized crushed stones: 76 liters per m^3
Type of measure(s)	Structural (green)
	Enhancing pervious surface (green infrastructure)
Relevant entities:	
Implementation	Yokohama City
O&M	Same as above
Finance	Same as above
Construction period:	Construction: 1987–89
	Renovation work: 2015–17
Cost:	Approximately ¥1.8 billion ($16 million) budget for a 2.3 ha site, including the renovation of garden paths and facilities[a]
Additional benefits and functions:	Establishment of green spaces and public amenities
	Urban development
	Mitigation of heat island effect
Sources:	Chigira 2017, unless otherwise noted.
	a Yokohama City 2017.

Context: Urban and Flood Risk Contexts

The vision to develop a new urban center along **Yokohama City's** waterfront, the so-called **Minato Mirai 21** (MM21) project, was first conceptualized in 1965 in light of the rapid urbanization of the 1950s. The large-scale urban redevelopment of MM21 was initiated in 1983, with one of the aims of achieving environmental sustainability and disaster resilience, including the integration of measures for earthquakes, tsunamis, and coastal floods as a key element to inform the design and implementation of the overall MM21 Master Plan.

With the establishment of high-quality public spaces and key greenery aspects of the master plan, the original Grand Mall Park was partially completed in 1989 (Chigira 2017). As new commercial and residential buildings started gradually to increase in the surrounding areas, however, the original design and facilities of the park became outdated. In addition, increasing numbers of residents and tourists visiting the site necessitated the reestablishment of the park to meet the growing demand and accommodate users' needs, as well as to enhance the water circulation that had been disrupted over the years of development in the surrounding area. For these reasons, Yokohama City initiated the renovation of the Grand Mall Park in 2015 (Environmental Planning Bureau, Yokohama City 2015). A key feature introduced in the new design was vertical water circulation, which is derived from the concept of green infrastructure.

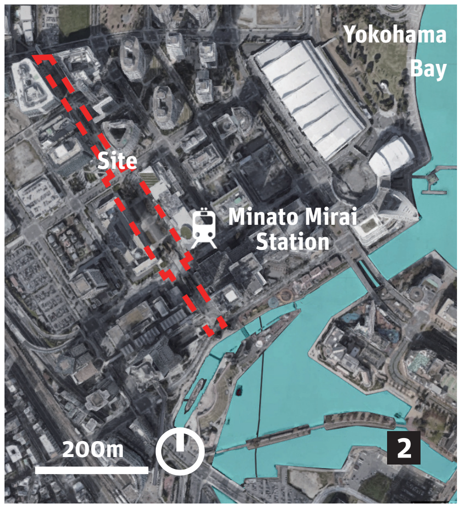
Solution: Investment Design and Key Features

Investment Design

Grand Mall Park is a green pedestrian axis 25 m in width that connects the station to the waterfront. The whole site of the park is 23,000 m^2 in area and it sits among commercial buildings, retail businesses, and museums (Environmental Planning Bureau, Yokohama City 2018). The park has a number of tall zelkova trees and unique street furniture with a sea waves feature (**figures A15.3** and **A15.4**); the concept of vertical water circulation is implemented at the level of the pavers and beneath them. A stormwater storage macadam lies beneath a 700 m pervious pavement and retains rainwater that comes through infiltration gutters, pervious pavements, and planting beds (Green Infrastructure Research Institute Association 2016).

Key Features

- **High-capability material for stormwater storage:** In contrast to standard single-sized crushed stones, rainwater storage macadam can promote the growth of tree roots and effectively store and release rainwater owing to its high water-absorbing ability and water-retentive function. The stormwater storage macadam used in Grand Mall Park has a 5 percent water retention capacity at the surface of the stone; hence, it retains 50 liters per cubic meter (L/m^3). Additionally, it is mixed with humus, which retains twice as much water (214 L/m^3) as general soils (108 L/m^3). The combination brings the water storage capacity beneath the paving of Grand Mall Park up to 76 L/m^3 (Chigira 2017). Before the renovation, stormwater from the park was drained through U-shaped gutters. Now, vertical water circulation contributes to the storage of stormwater runoff, some of which is then allowed to evaporate to



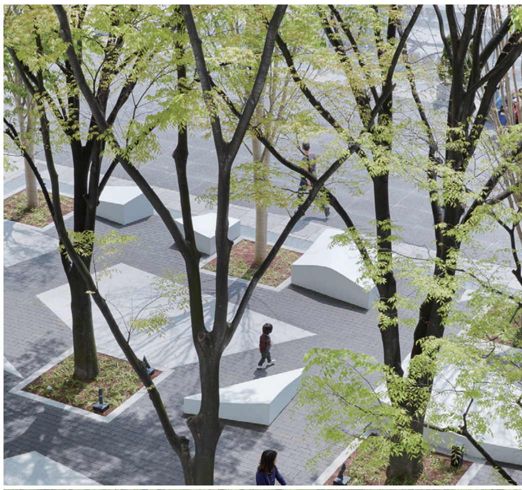
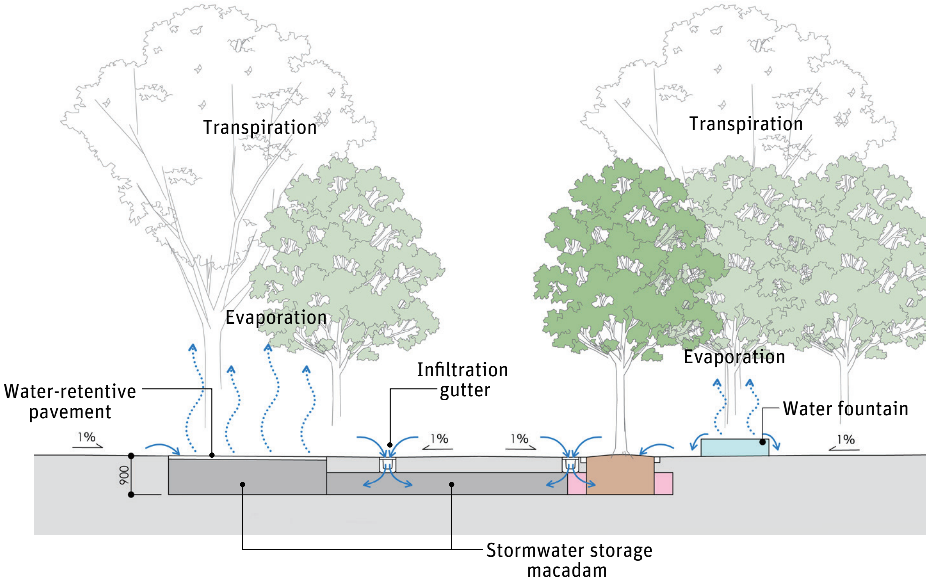


Figure A15.1: Overall View of the Site
Photo Credit: Forward Stroke Inc.

Figure A15.2: Site Context
Source: Google Earth. *Note*: m = meter.

Figure A15.3: The Grand Mall Landscape Design
Photo Credit: Forward Stroke Inc.



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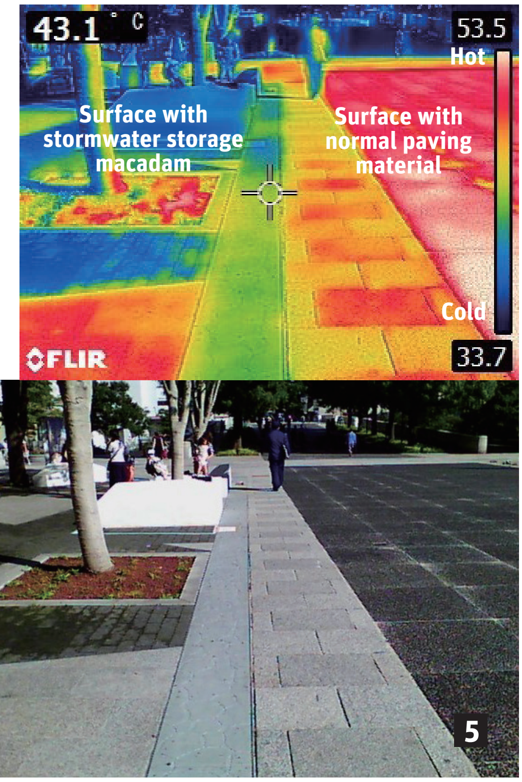

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Figure A15.4: Conceptual Diagram of the Green Infrastructure and Hydraulic Cycle

Source: Based on information from Environmental Planning Bureau, Yokohama City (2018).

Figure A15.5: Demonstration of Heat Island Mitigation Effect

Source: Environmental Planning Bureau, Yokohama City (2018).

reduce the surrounding temperature and some of which is used by the trees to grow. With the planting of more trees and groundcover as part of the redevelopment, the proportion of green spaces at Grand Mall Park has increased from 34 percent to 46 percent (Manabe 2018).

- **Dual purpose of flood management and microclimate enhancement:** The park combines its stormwater management function, as described above, with enhancement of the microclimate for its visitors. In sunny conditions, the water stored in the macadam is slowly released back into the air through the pervious pavers as part of a natural evaporation system, and the temperature at the ground level drops. In other words, people sitting on the benches will feel cooler air at their feet, while enjoying the shade from the tree canopy above (Kida 2017).

Results: Both Stormwater Storage and Cooling Benefits

The landscape architect of Grand Mall Park chose a material that holds water in the subsurface layer and enhances stormwater detention capacity beneath the urban plaza. Although the amount of water each stone can hold is limited, the filling of up to 23,000 m^2 of space with such material collectively reduces the amount of runoff to a substantial degree. An additional unique feature of this material is that it releases water to the air in dry conditions, an effect that can be measured by gauging the microclimate of the plaza. When rainwater storage macadam was first introduced at Grand Mall Park in 2016, Yokohama City conducted a study to compare the effects with and without the material in the park. A thermography image produced by the analysis shows the outstanding effects that were observed (**figure A15.5**), with remarkable cooling indicated by the temperature right above the macadam.[22]

22 Detailed information is provided by Chigira (2017), Nojima et al. (2017a, 2017b), and Odagiri (2018).

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Figure A16.1: Renewal of Sewer Pipes (before and after)
Source: Bureau of Finance, TMG n.d.

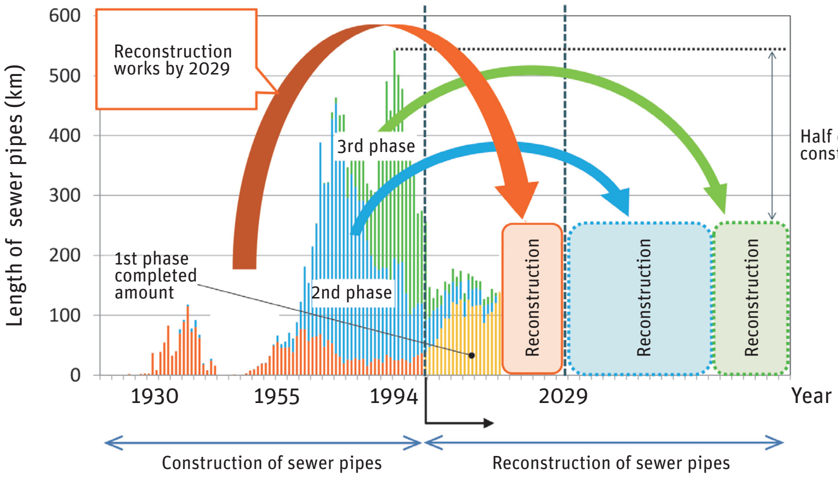
Case 16: Implementing Preventive O&M of Sewerage Facilities through Asset Management: Tokyo's Central Wards

Location:	Tokyo's 23 central wards, 621.5 km^2 in area and with a population of 9.5 million[a]
Site characteristics:	Dense urban areas with high concentrations of assets and population
Flood management measure(s):	
Flood type	Surface water
Management capacity	Based on the revised Tokyo Basic Policy for Heavy Rain Management 2014, the flood management target for sewerage facilities is set at 50 mm/hour. Areas with higher risk of surface water flooding, however, have an upgraded target of 75 mm/hour (refer to **Knowledge Note 2** and **case 6** in this appendix).
Type of measure(s)	Innovative methodologies for conducting sewerage facilities' O&M
Relevant entities:	
Implementation:	TMG
O&M:	Same as above
Finance:	TMG. MLIT offers subsidies for planning, inspection, and reconstruction work, based on the asset management method[b]
Construction period:	Not applicable
Cost:	Not available
Additional benefits and functions:	Seismic resilience
Sources:	Bureau of Sewerage, TMG (2016), except where otherwise noted.
	a Statistics of Tokyo 2019. b MLIT 2018.

Context: Aging Sewerage Facilities in Need of Upsizing to Accommodate Increasing Risk of Surface Water Flooding

Although **Tokyo's central area** is almost entirely connected to a centralized sewerage system managed by TMG, its age and size have presented a serious problem in the face of growing flood risks. Sewerage facilities in central Tokyo were established around 1955 as rapid urbanization and economic development were underway, and 100 percent connection was achieved in the central wards by 1994, with the total length of sewerage pipes having reached 16,000 km. Approximately 1,800 km of this extent, however, has already exceeded the end of its service life—an amount that will increase to 8,900 km in the next 20 years (Bureau of Sewerage, TMG 2016).

This is a critical concern for managing urban floods in Tokyo, given that 82 percent of its central wards have adopted combined sewerage systems. Sewerage facilities in most of central Tokyo are also responsible for draining stormwater to mitigate the risk of surface water flooding. In this highly urbanized environment, the trend of recent years toward increasingly intense rainfall imposes a growing risk of socioeconomic damage. As a basic requirement, there is an urgent need to upsize the conveyance



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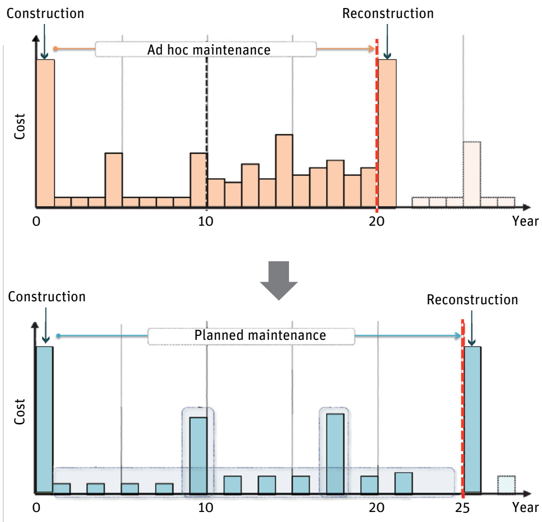

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capacity of old sewerage pipes laid before 1986[23] to meet a 50 mm/hour rainfall target. In addition, districts identified as flood prone (refer to **case 6** in this appendix for more details) require further upsizing to accommodate 75 mm/hour storm events. The need to renew aging sewerage facilities can become an opportunity to upsize them at the same time as accomodating the most recent rainfall intensity targets.

The most urgent need confronting TMG is to upgrade the many aging sewerage facilities that will reach the end of their service lives at almost at the same time (**figure A16.2**), and doing so at such a large scale is a challenge in itself. The challenge of carrying out this reconstruction work is further compounded by the high urban density of central Tokyo. Beneath any road in Tokyo, for example, various types of infrastructure, such as electricity grids and gas pipes, are installed in addition to sewerage pipes, which makes access to the pipes very difficult. As the impact of pipe reconstruction work on road traffic and economic activities must be kept to a minimum, keeping relevant administrators and local community members closely coordinated is essential and, in most cases, a time-consuming process. In addition, since sewerage and drainage functions cannot be stopped at any moment, bypass pipes must be laid before the reconstruction work commences, to ensure continuous flow of combined sewerage and stormwater. The same applies to pumping stations and wastewater treatment plants, as well, which drives the cost of reconstruction even higher.

Solution: Investment Design and Key Features

Investment Design

In light of these conditions and challenges, TMG, in partnership with MLIT, is working (i) to enhance O&M of existing sewerage infrastructure to extend its service life, as well as monitoring and repairing infrastructure, and (ii) to identify cost-effective ways to carry out reconstruction and expand the sewerage facilities in partnership with other sectors and stakeholders.

TMG enhanced O&M of the sewerage facilities by implementing a new asset management method, in accordance with MLIT's guidelines for asset management for public sewerage infrastructure. The method focuses on holistic, systemwide assessment and planning, rather than taking a facility-level approach (MLIT 2015). With a sewerage system as large as that in Tokyo, for example, conducting inspection and repair work for every facility on a regular basis is not feasible[24] because of constraints on human resources, time, and available budgets. An understanding of the current as well as the future state of the system as a whole

Figure A16.2: Schematic Asset Management Plan for the Sewer Pipes in Tokyo's 23 Central Wards

Source: Modified information based on Bureau of Sewerage, TMG (2016). *Note*: km = kilometer.

Figure A16.3: Comparison of Asset Management Method (bottom) with Conventional Method (top)

Source: Modified information based on Bureau of Sewerage, TMG (2016).

23 "Visions for Comprehensive Flood Management in TMG: Report 61 to the Governor of Tokyo," was published in July 1986, when the combined flood management target for river and sewerage improvement was set at managing 50 mm/hour rainfall (TMG 1986).

24 As specified in "Manuals for Developing O&M Plans of Sewer Pipes" (for more information, see MLIT n.d.), and "Guidelines for Sewerage O&M: 2014 Edition" (for more information, see Japan Sewer Collection System Maintenance Association n.d.), among others. According to these O&M manuals, annual inspection is suggested, for example, for sewer pipes and manholes that are 30 years old or more, while recommended once every three years for those that are newer.

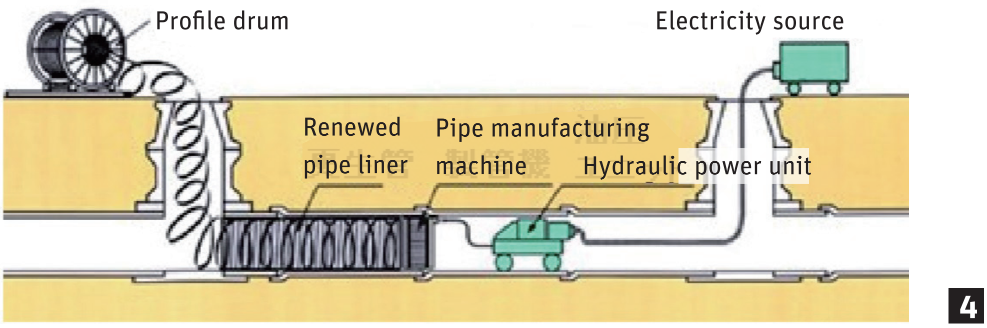

Figure A16.4: Schematic Illustration of Sewer Pipe SPR Rehabilitation Technology

Source: Modified information based on Bureau of Finance, TMG (n.d.).

will allow better prioritization of TMG's O&M action plan, through the avoidance of redundancy and unnecessary reconstruction work, and the prioritization of preventive O&M, such as repairs and anticorrosion treatments, to extend facility life as much as possible (**figure A16.3**).

With respect to cost- and time-effectiveness, TMG is implementing various solutions to enhance its aging sewerage facilities by (i) establishing a holistic framework to plan the entire process up front, taking into account the limited time and financial resources; (ii) clarifying priorities in terms of what actions (inspection, repair, or reconstruction) are to be taken where and when; (iii) combining the work with surface water flooding mitigation measures; and (iv) utilizing innovative technologies to expedite the process with minimal impact on the surrounding urban setting.

Key Features

- **Database development for a 16,000 km–long sewerage network:** TMG created a database for its sewerage system, recording the locations, depths, installation years, and types of pipes. This large set of geospatial information serves as the base for storing monitoring and inspection data, as well as information on planning the renewal of aging sewerage facilities (Morikawa 2018). By analyzing information collected through precise investigation of the deterioration level at each facility, for example, TMG can allocate specific amounts of time and costs required for reconstruction work and include them within its asset management plans. In 2005, TMG made part of this information available to the public through an online platform called SEMIS (Sewerage Mapping and Information System).
- **New technology for sewerage reconstruction:** To minimize disruption to sewerage services during the reconstruction process, various new technologies were developed in partnership with the private sector. The sewage pipe renewal (SPR) method, for example (schematically illustrated in **figure A16.4**), coats the inside of sewer pipes with materials made of vinyl chloride. The coating enhances structural stability against earthquakes and allows the continuous flow of wastewater and stormwater even during installation. Rehabilitation can take place without interfering with existing roads and infrastructure, resulting in a cost reduction of approximately 35 percent compared to conventional methods (MLIT 2014).[25] This Japanese private technology has been introduced to the global market as well and implemented in countries whose sewerage systems are subject to similar aging (Bureau of Sewerage, TMG 2015).

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25 Compared to conventional reconstruction work, the SPR rehabilitation method can reduce costs by an average of ¥15.6 million ($142,000) per 30 m extension of underground sewerage pipe (width 1,670 mm x height 1,500 mm), a 35 percent cost reduction.

26 An economic life can be calculated based on when the annual average cost of facilities' installation and O&M combined becomes the lowest. Annual average cost can be calculated by dividing the total life-cycle cost (construction and O&M) by the duration of operation.

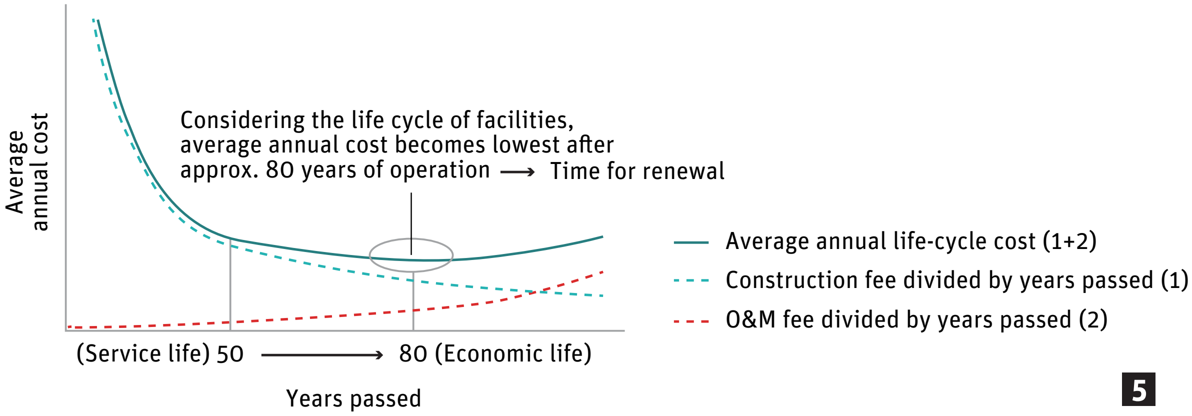

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Figure A16.5: Asset Management Time Flow of Sewerage Pipes

Source: Modified information based on Morikawa (2018).
Note: O&M = operation and maintenance.

Results: Cost Savings from Extended Service Life

Through effective asset management, the service life of TMG's sewerage facilities has been extended by 30 years. Facilities whose service lives are normally 50 years were able to reach their economic lives[26] in approximately 80 years (Bureau of Sewerage, TMG 2016; see **figure A16.5**). Similarly, this approach has been applied to other kinds of facilities (such as pumping stations and wastewater treatment plants) and various types of equipment (such as mechanical and electric components) and has contributed to extending their economic lives through preventive repairs and reconstruction work.

The average annual life-cycle cost can potentially be reduced approximately 20 percent, from ¥290 million/year to ¥240 million/year, or $2.63 million/year to $2.18 million/year (Bureau of Sewerage, TMG 2016).

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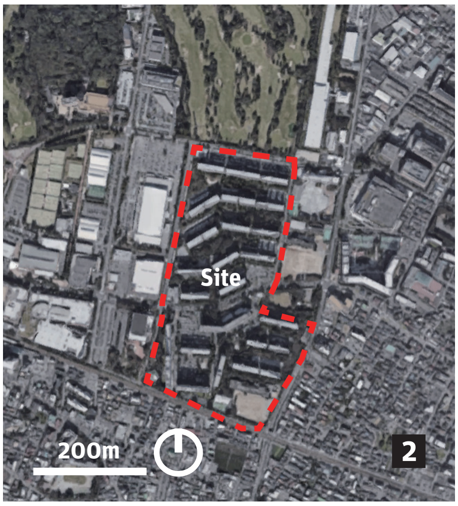
Case 17: Monitoring and Evaluating the Impact of Surface Water Flood Management: Akishima Tsutsujigaoka Collective Housing

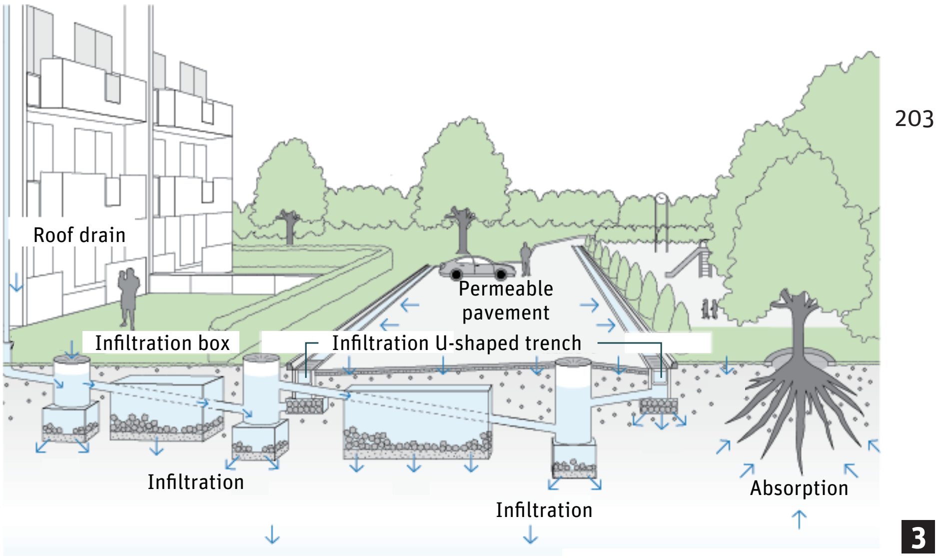
Location:	Akishima City, Tokyo, located 35 km west of the center of Tokyo
Site characteristics:	Urban area (commercial, residential, and public facilities) with low to medium density
Flood management measure(s):	
Flood type	Surface water
Management capacity	Not applicable
Type of measure(s)	Structural (gray and green)—enhancing stormwater infiltration
Relevant entities:	
Implementation	Urban Renaissance Agency (UR) and MLIT
O&M	UR, including long-term monitoring
Finance	UR
Construction period:	1977–81
Cost:	Not available
Additional benefits and functions:	Urban development (housing)
	Environmental conservation and sustainability
	Open space and public amenities
Sources:	Hayashi, Shimada, and Morikami 2002.



Context: Increasing Flood Risks Due to Urban Development

To address the substantial increase in stormwater runoff brought about by rapid urban development since the 1950s, more diversified methods were needed in **Akishima City** for urban flood risk management. Lack of data on the flood management effectiveness of new technologies and approaches presented a barrier, however, to the adoption of more multipurpose, nature-based solutions. In 1978, therefore, housing developer Urban Renaissance Agency (UR), under the direction of MLIT, embarked on an exploration of new ways to manage urban stormwater, with a particular focus on finding measures that could optimize the use of limited urban land while keeping the costs of construction and maintenance low.

Akishima Tsutsujigaoka Collective Housing, a 27.8 ha residential neighborhood that is home to 2,673 households (**figures A17.1**), was selected as the first pilot site for the joint initiative by UR and MLIT. A Committee for the Study of Stormwater Processing Systems within the Apartment Complex was established to test innovative stormwater management measures.



Solution: Investment Design and Key Features

Investment Design

The various new technologies and approaches tested included infiltration containers (49 items), an infiltration trench (494 m in length), an infiltration U-shaped gutter (143 m in length), and permeable pavement (3,580 m^2 in area; Hayashi, Shimada, and Morikami 2002). Using a stormwater infiltration system that combined all these technologies and approaches, UR initiated an effort to manage stormwater by imitating the natural process of the hydraulic cycle. Through this system, stormwater would infiltrate the subsurface level (**figures A17.3** and **A17.4**), which would not only minimize the amount of runoff that would flush immediately to the outside drainage system, but would also recharge the groundwater and return it back to the natural water cycle. This nature-based solution, as a result, would prevent the depletion of nearby rivers—another environmental challenge faced by rapidly urbanizing areas in Tokyo.

Key Features

- **Thorough assessment of site conditions and geology to inform intervention design:** The location of the stormwater infiltration interventions were determined based on a thorough site assessment, taking into consideration ground-level conditions, such as (i) underground water level, (ii) the permeability degree of topsoil, and (iii) the possibility of slope failure and groundwater pollution (MLIT 2010). The feasibility assessment clarified that the site is located above the mildest slope of the Tachikawa fluvial terrace, and groundwater exists approximately 10 m below the surface. The targeted layer for stormwater infiltration was the loamy layer or the layer of earth that was brought to the site during construction. The permeability coefficient of the loamy layer was within the range of 1.5×10^{-4} cm/s to 4.8×10^{-7} cm/s, according to laboratory testing, a range suitable for adequate water percolation (Hayashi, Shimada, and Morikami 2002).
- **Monitoring and evaluation of impacts over time:** A key objective of the pilot was to monitor and evaluate the flood management effectiveness of the stormwater infiltration system by gathering quantitative data. UR therefore carried out O&M and data gathering for more than 30 years, beginning in 1981 (Shouji 2014). Parameters recorded included rainfall and runoff (discharge) volume. A comparative analysis method was used to evaluate flood management effectiveness by monitoring the same parameters at a comparison study site within the property, 3.2 ha in area, that utilized conventional construction methods without any infiltration system (Hayashi, Shimada, and Morikami 2002).

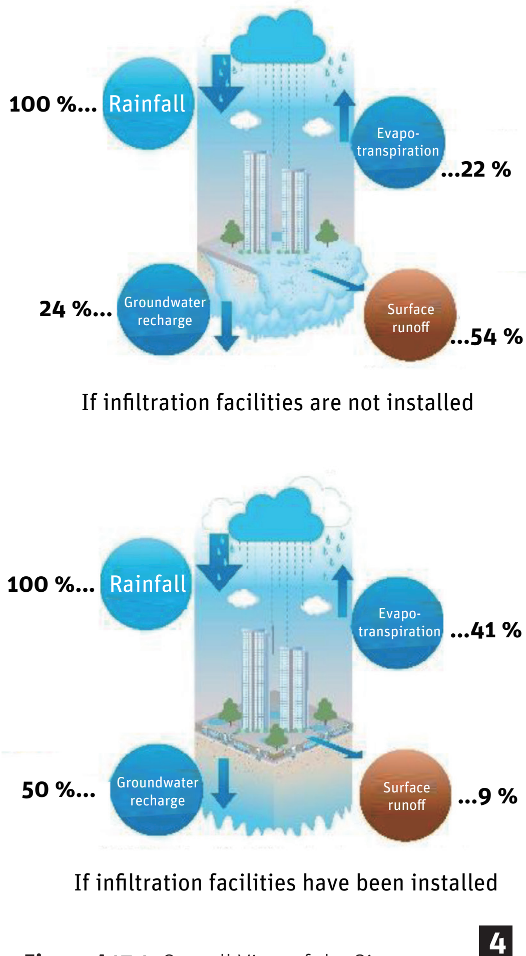


Figure A17.1: Overall View of the Site
Photo Credit: Kenya Endo.

Figure A17.2: Site Context
Source: Google Earth. Note: m = meter.

Figure A17.3: Conceptual Diagram of the Infrastructure
Source: Based on information from UR (n.d.[a]).

Figure A17.4: Impact of Stormwater Infiltration System on Annual Water Balance
Source: UR n.d.(b).

Figure A17.5: Building Units and Surrounding Landscape and Parking Lots

Photo Credit: Kenya Endo.

Figure A17.6: Impact of the Stormwater Infiltration System of Akishima Tsutsujigaoka Collective Housing.

Source: UR n.d.(b).

Results: Substantiating Stormwater Management Effectiveness with Data

The 30 years of monitoring yielded clear evidence of the effectiveness of the stormwater infiltration system for surface flood management. Data showed that areas adopting the system reduced their stormwater runoff to one-quarter to one-fifth of the runoff of areas that did not install it (**figure A17.6**). UR has published the results of the long-term monitoring, as well as the outcomes of its follow-up surveys in 1992, 1995 (the 15-year anniversary of system implementation), 2002 (20-year anniversary), and 2012 (30-year anniversary; Shouji 2014). Based on this evidence of its efficacy, the system was installed at nearly 300 housing projects in Japan, across a total of 220 ha, between 1982 and 2002 (UR n.d.[a]).

The results of the Akishima Tsutsujigaoka Collective Housing pilot demonstrate the need for long-term monitoring and evaluation of the effectiveness of new technologies in managing urban flood risk, including both gray and green solutions, and showed the opportunity that can be created by good monitoring and evaluation in scaling such initiatives.

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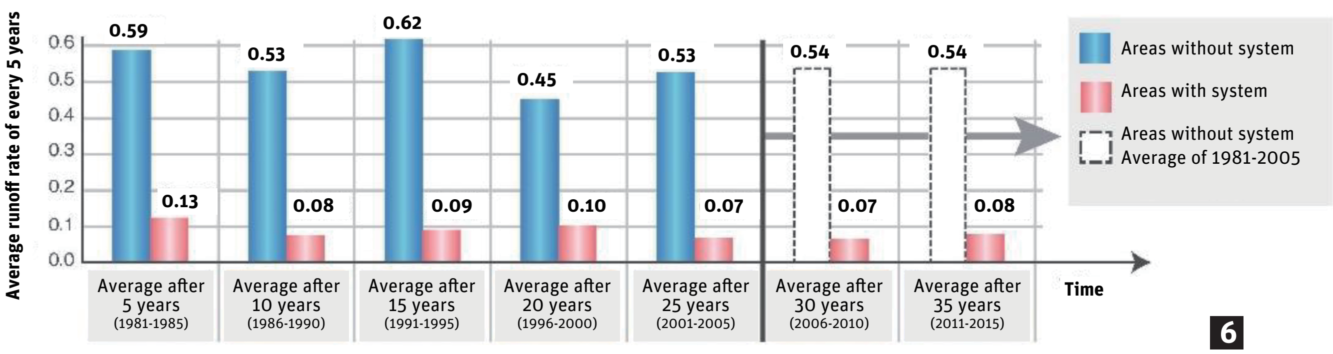


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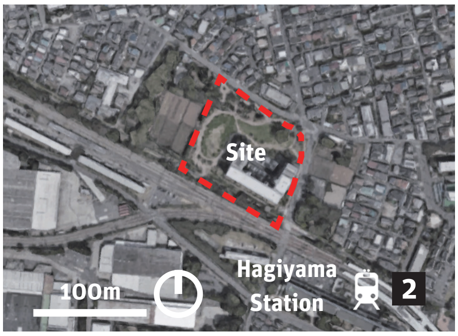
Case 18: Managing Surface Water Flood Risk through Private Sector Engagement:
Brillia L-Sio Hagiyama Owner's Park and Hagiyama Shikinomori Park

Location:	Higashimurayama City, Tokyo
Site characteristics:	Northern part of the Tama area with a population of approximately 150,000, 25 km west of central Tokyo. "Satoyama" (secondary woodlands) and green fields remain around the site.
Flood management measure(s):	
Flood type	Surface water
Management capacity	Not applicable
Type of measure(s)	Structural (green)
	Enhancement of pervious surfaces by increasing green spaces
Relevant entities:	
Implementation	Brillia L-Sio Hagiyama Owner's Park (14,899.77 m^2), including residential building for 184 households, and Hagiyama Shikinomori Park (TMG-certified private park, comprising 10,429.84 m^2 of Owner's Park area), implemented by Tokyo Tatemono Co. Ltd., and the Seibu Railway Co. Ltd. (private developers), with guidance from TMG
O&M	Brillia L-Sio Hagiyama Owner's Park: Tokyo Tatemono Amenity Support Co. Ltd.
	Hagiyama Shikinomori Park: Private developers and residents/landowners, in accordance with TMG's certified private park mechanism
Finance	Same as above
Construction period:	Completion date: July 30, 2009
Cost:	Not available
Additional benefits and functions:	Increase in public recreation space
	Environmental conservation and sustainability
	O&M of parks shared by community and private operator through participatory approach
	Disaster evacuation park and facilities established
Sources:	Real Estate Baseball Association 2009.



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Context: Urban Development and Flood Risks

Higashimurayama City is exposed to flooding from neighboring small- to mid-sized rivers, as well as surface water flooding caused by heavy rain in the urban areas. The conservation of green fields and the creation of park lands are considered watershed countermeasures that mitigate stormwater runoff by increasing infiltration capacity.

A TMG-certified privately developed park system was initiated by TMG in 2006 in recognition of the growing need to establish green spaces and parks to increase urban infiltration capacity for surface flood management; reduce temperatures in

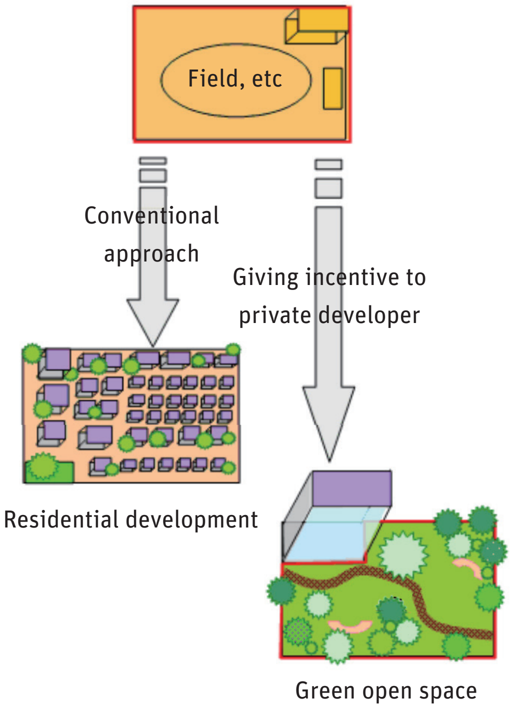

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Figure A18.1: Overall View of the Site

Photo Credit: Kenya Endo.

Figure A18.2: Site Context

Source: Google Earth. *Note*: m = meter.

Figure A18.3: Schematic Diagram of Privately Developed Park System

Source: Modified based on information from Bureau of Urban Development, TMG (2016).

Figure A18.4: The Park and Housing Blocks

Photo Credit: Kenya Endo.

cities during the summer and mitigate the urban heat island effect; enhance environmental conservation and sustainability; and create attractive living spaces for citizens. The high cost of land and maintenance, however, made it challenging to advance the development of new public parks and green spaces through public sector efforts alone.

Solution: Investment Design and Key Features

Investment Design

The first TMG-certified privately developed park was established in Higashimurayama City in 2009, in conjunction with a private housing development initiative by Tokyo Tatemono Co. Ltd. and the Seibu Railway Co. Ltd. Integration of the TMG-certified privately developed park within the development design enabled the newly established Brillia L-Sio Hagiyama Owner's Park (a private housing development with 184 new apartment units) and Hagiyama Shikinomori Park (a public park) to have 70 percent of their developed area (nearly 1 ha) as a green space, offering rich biodiversity while also functioning as a disaster evacuation park.

The TMG-certified privately developed park system enabled the private developers to integrate green areas into their designs under certain conditions: that they (i) would open certain portions of the site to the public; (ii) would carry out effective O&M, meeting accreditation criteria for disaster evacuation; (iii) would conduct O&M for at least 35 years; and (iv) would collectively manage all expenses. In turn, TMG would provide benefits to the developers, including such supporting measures as the deregulation of building codes in the park space and the reduction of the costs of land ownership (Bureau of Urban Development, TMG 2016). Furthermore, through this system, TMG would allow private developers to construct buildings, such as high-rise condominiums, in areas otherwise designated for parks and green spaces.

Additionally, the TMG-certified privately developed park system has provided an incentive to private land owners to participate in park maintenance by waiving property and urban planning taxes for 10 years and reducing inheritance taxes by 40 percent if the land is leased for more than 20 years.

Key Features

Private sector and community financing mechanism for urban green spaces: Utilization of the TMG-certified privately developed park system allowed for various incentives for private sector and community financing to establish and maintain new urban green spaces. TMG allowed height deregulation, for example, permitting apartment buildings to be as high as 34–35 m with 11 stories. The site's land right is owned by the apartment management association, which pays a monthly fee of ¥250,000 (roughly $2,200), or ¥1,400 ($12.70) per apartment unit, as the park maintenance fee, which is separate from the apartment maintenance fee. In addition, if the park is opened to the public for free, its property and city planning taxes are further reduced. The private enterprises own property rights over the park area and take care of the park's O&M as part of a 35-year contract with the apartment management association. TMG carries out O&M only of the public restrooms in the park.

A similar system in Japan, called the commercial enterprise management system (Park-PFI), also supports sustainable park O&M by enabling private sector financing and reducing the public sector's financial burden. This system allows private enterprises, such as restaurants and shops, to establish for-profit facilities inside parks. In return, the private enterprises hire individuals who carry out maintenance and repair work for the park facilities, including garden paths and plazas. This new O&M management method aims to increase the comfort and convenience of park visitors. In addition, the system improves the quality of urban parks by attracting private investment and, as a result, reducing the financial burden of O&M on the park administrator (MLIT 2018).

In addition, TMG utilizes the Tokyo Metropolitan Park Supporter Fund (Tokyo Metropolitan Park Association, n.d.). The fund collects donations from Tokyo citizens and is used for community events in the parks, such as traditional performing arts projects at Hamarikyu Gardens and concerts at Hibiya Park. Part of the profit generated from the cafe at the Komazawa Olympic Park also contributes to this fund.

Results: Private and Public Sector Partnership for a Multipurpose Urban Flood Risk Management Investment

The financing of parks and green spaces provides significant flood management, disaster risk management, and environmental sustainability benefits to cities. Financing the considerable life-cycle cost of these investments, however, can be difficult for the public sector to bear alone, particularly in urban areas with high land value. The utilization of the TMG-certified privately developed park system to develop and maintain the housing and park complex at **Higashimurayama City** is an example of how the private sector and landowners can be engaged and given incentive to share the financial and maintenance costs and responsibilities for the establishment of new, high-quality green spaces in urban areas. Such spaces serve multiple purposes and carry benefits including, but not limited to, flood risk management.

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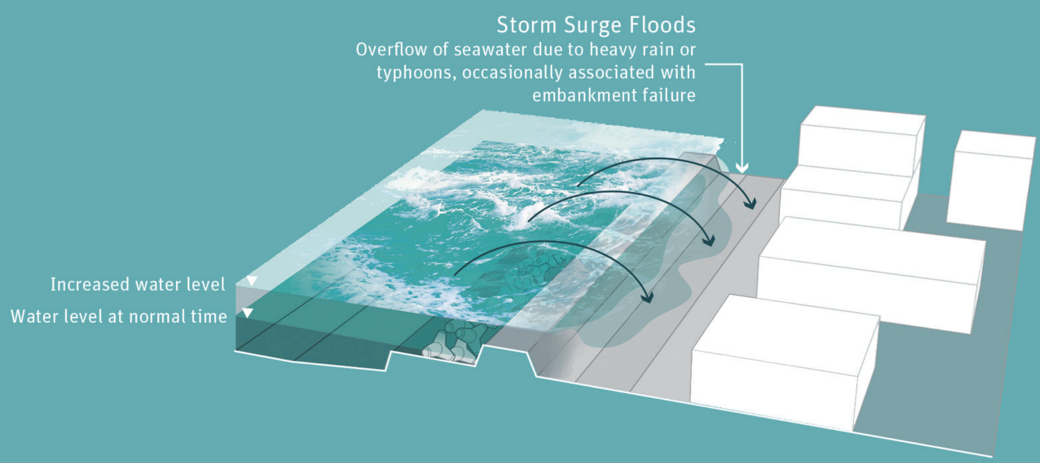
Storm Surge Floods



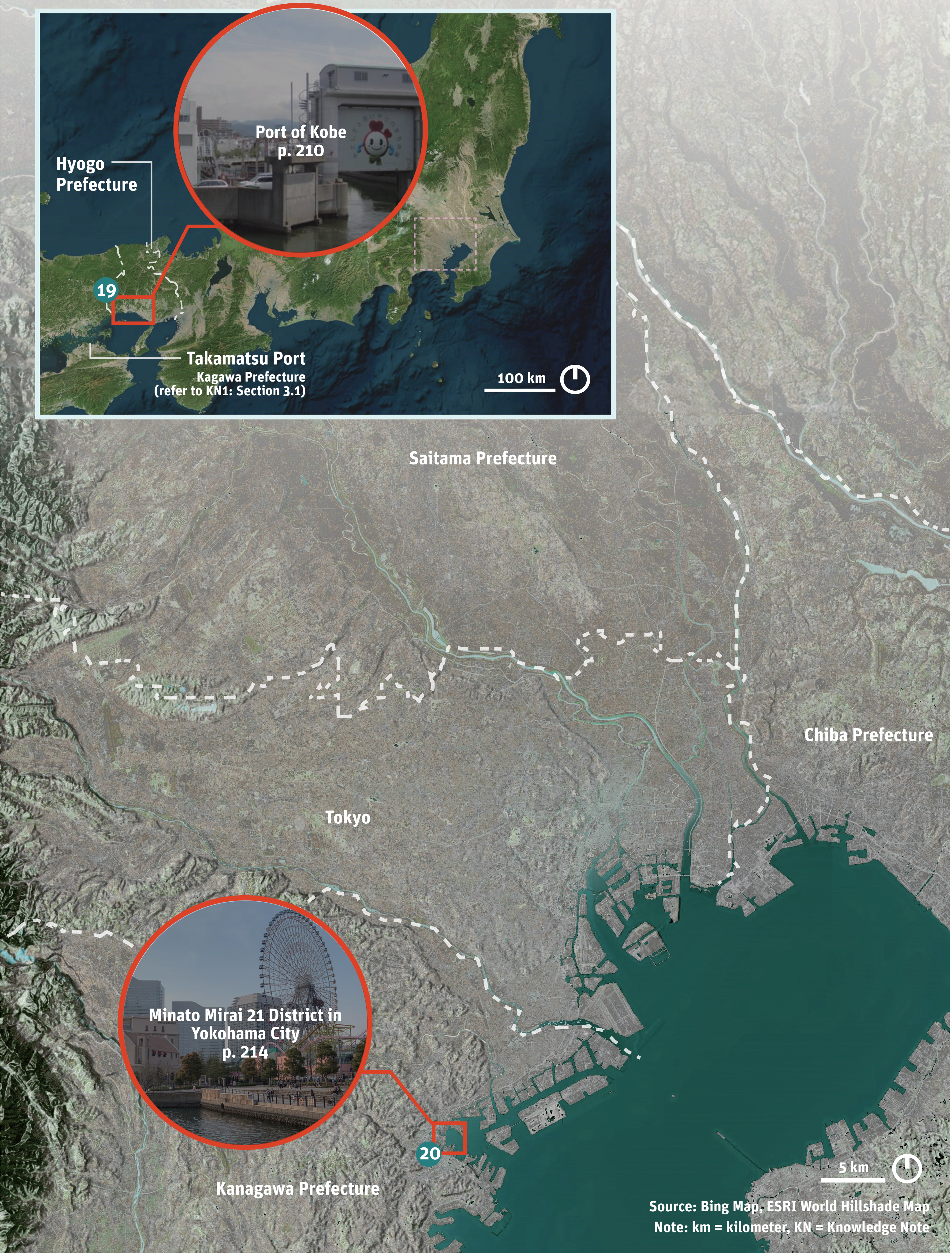

Port of Kobe
p. 210
Hyogo Prefecture
19
Takamatsu Port
Kagawa Prefecture
(refer to KN1: Section 3.1)
100 km
Saitama Prefecture
Chiba Prefecture
Tokyo
Minato Mirai 21 District in Yokohama City
p. 214
20
Kanagawa Prefecture
5 km
Source: Bing Map, ESRI World Hillshade Map
Note: km = kilometer, KN = Knowledge Note



Figure A19.1: Storm Surge Measures in Kobe, —Iron Tide Gate, Flood Gate, and Pump Station
Source: Takemoto 2019.

Case 19: Managing Storm Surge Flooding by Enhancing Seawalls and Flood Gates: Port of Kobe

Location:	Kobe City, Hyogo Prefecture
Site characteristics:	High urban port city located on the north shore of Osaka Bay. Sixth-largest city in Japan with population around 1.5 million. Ports, industrial zones, and commercial and residential developments are densely located around the waterfront area.[a]
Flood management measure(s):	
Flood type	Storm surge flooding
Management capacity	Seawalls: Storm surge—designed to manage up to T.P.[b] + 2.80[c] (that is, to manage the worst typhoon events in history); tsunami—designed to manage up to M8[d] earthquake (projected Nankai Trough Earthquake level)
Type of measure(s)	Structural: 59.8 km of storm surge management measures at the Port of Kobe, including iron tide gate, pump stations, and flood gates
Relevant entities:	
Implementation	Port and Harbor Bureau, Kobe City Government
O&M	Same as above
Finance	Port and Harbor Bureau, Kobe City Government with support from MLIT
Construction period:	1965–2015
Cost:	Approximately ¥30 billion ($273 million)
Additional benefits and functions:	Seismic resilience and tsunami protection
Sources:	Kobe City n.d.(b), except where otherwise noted.
	a MLIT 2017.
	b Tokyo Peil (T.P.) datum corresponds to the mean sea level in Tokyo Bay.
	c Kobe City n.d.(a).
	d Japan Meteorological Agency Seismic Intensity Scale.

Context: Port Development and Flood Risks

As a major port city in Japan, **Kobe City** has its people and assets concentrated across the coastal area, where they are exposed to significant risks of coastal floods caused by storm surges and tsunamis. Kobe Port, opened in 1868, is a key hub of international and domestic marine transport. It provides vital support to Japanese and global industries and is one of the major international container hubs in the world.

Large portions of Kobe's coastlines are built on reclaimed land, and, historically, the city has experienced numerous devastating flood events from storm surges, including Typhoon Wilda (No. 20) and Typhoon Shirley (No. 23), which hit Kobe City in consecutive years (1964 and 1965) and affected more than 30,000 people (**figure A19.3**). More recently, in 2018, Typhoon Jebi (No. 21) brought maximum wind speeds of more than 45.3 m/sec, maximum hourly rainfall of 59 mm/hour, tides reaching a level of T.P.[27] + 2.33 m, and waves recorded at 4.72 m. Typhoon Jebi injured 5 people and damaged more than 300 houses (Hyogo Prefecture 2018). The Port of Kobe was severely affected, with 43 containers washed away and transportation networks and industrial zones disrupted by inundation.

To manage this significant risk of coastal floods, the Coastal Disaster Prevention Department of the Engineering Works and Disaster Prevention Division of the Kobe Ports and Harbors Office (i) works to manage coastal protection zones; (ii) plans, designs, and coordinates tsunami and storm surge protection projects throughout the city; (iii) monitors and maintains protection facilities; and (iv) comprehensively coordinates the office's activities for disaster prevention, shoreline measures, and other related matters.

Solution: Investment Design and Key Features

Investment Design

In response to the severe coastal flooding experiences of the 1960s, Kobe City has, since 1965, been implementing a Storm Surge Protection Project, investing for over five decades in flood management infrastructure across 59.8 km of the city's coastlines. Seawalls, iron tide gates, and pump stations have been set up in the coastal areas to prevent the overflow of seawater from storm surges (**figures A19.1** and **A19.4**).

The design standard for the various types of infrastructure is to be able to manage a storm surge (typhoon) equal to that of the most severe events in history. For Kobe, these are the 1959 Ise Bay Typhoon, in terms of size (rain intensity, wind speed, and so on) and the 1934 Muroto Typhoon, in terms of tide level (influenced by the storm's path; **figure A19.5**).

These structural measures are combined with nonstructural measures, such as (i) strengthening the predisaster prevention system in areas of high flood risk by encouraging the development of business continuity plans; and (ii) improving the system for providing disaster prevention information to residents and workers in coastal areas by enhancing last-mile communication through loudspeakers and installing tide indicators and live cameras to share information in real time. The importance of such an integrated approach combining structural and nonstructural

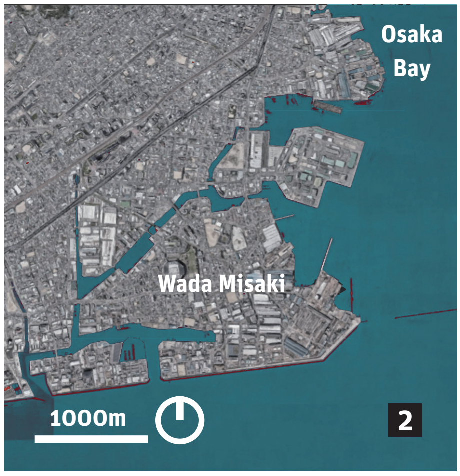
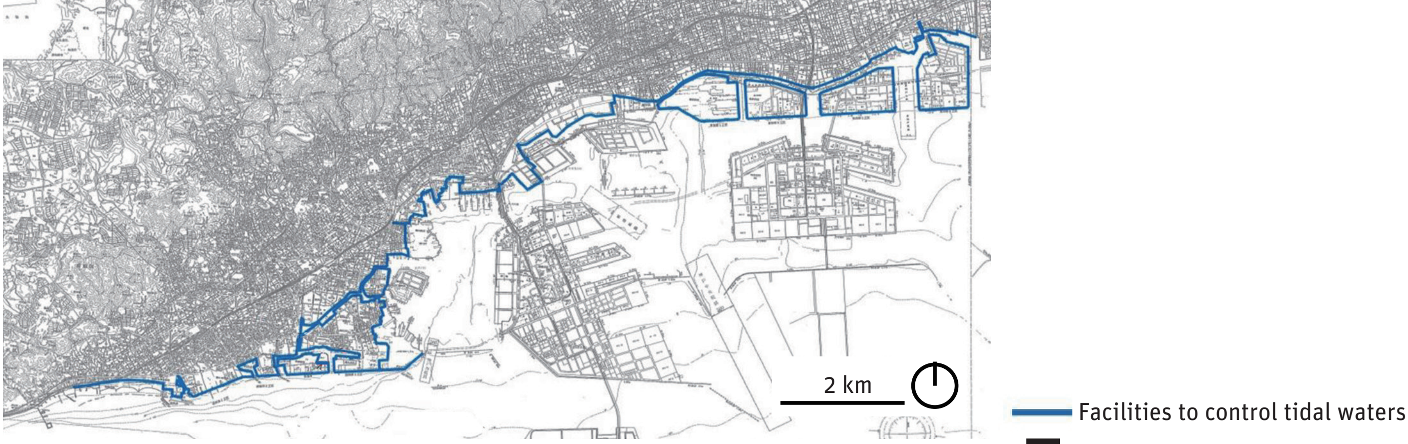


Figure A19.2: Site Context
Source: Google Earth. *Note*: m = meter.

Figure A19.3: Water-Covered Road and Riverbank Collapsed by Typhoon Shirley (No. 23) in 1965
Source: Takemoto 2019.

27 Tokyo Peil (T.P.) datum corresponds to the mean sea level on Tokyo Bay.



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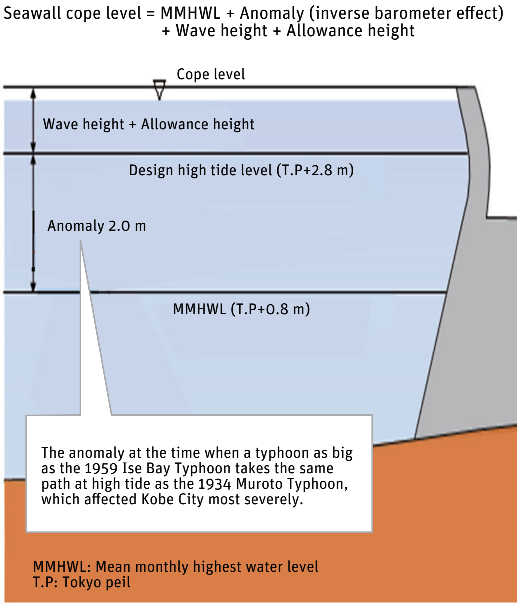

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Figure A19.4: The Storm Surge Protection Project 2-D Plan

Source: Takemoto 2019.

Figure A19.5: Design-Level Calculation of Seawalls Integrating Storm Surge Risks

Source: Takemoto 2019.
Note: m = meter; T.P. = Tokyo Peil datum which corresponds to the mean sea level on Tokyo Bay.

measures was borne out during the 2018 Typhoon Jebi event, and the city has since strengthened its efforts to encourage residents and workers to take predisaster prevention actions on their own.

Key Features

- **Incremental development and improvement:** Given the various types and the large extent of investments required to protect the port and city of Kobe from storm surge floods, the construction and improvement of structures has been incremental. This process is coupled with continuous review and improvement of the design of the structural measures, as well as the enhancement and implementation of nonstructural measures to address residual and unexpected risks. After Typhoon Jebi in 2018, for example, Kobe City, together with MLIT, the Japan Meteorological Agency, and experts from academia set up a committee to review the damage, draw lessons learned, and propose enhancements to the storm surge management measures for Kobe Port. Based on a thorough assessment of the damage, its causes, and bottlenecks in the post-Jebi review process, the committee proposed site-specific structural and nonstructural measures to enhance preparedness for future events. These included ground raising in targeted high-value areas, such as industrial yards; the fortification and raising of seawalls in targeted areas; enhancement of the installation of pumping facilities; review and improvement of evacuation sites and routes; improvement of disaster information communication systems; and review and improvement of the O&M of coastal embankments, among others (Kobe City 2019).
- **Use of innovative technology to ensure the safety of facility operators:** Kobe's coastal flood management measures are designed for both storm surge and tsunamis. The experience of large earthquakes, such as the Great Hanshin Awaji Earthquake in 1995 that affected Kobe and the Great East Japan Earthquake (GEJE) in 2011, has shown that enhancing not only the structure itself but also operational effectiveness and safety is key, particularly as the city prepares for a larger M8[28] Nankai Trough Earthquake. Quickly and safely closing the flood and tide gates is a critical concern. During the GEJE, more than 59 people reportedly died or went missing while attempting to close the gates (MLIT 2015). To tackle this issue, Kobe City has initiated the installation of a remote monitoring and operation system developed by NTT West that allows the flood and tide gates to be opened and closed from office computers and tablets and site conditions to be monitored in real time. The installation is expected to be completed at 15 sites by 2019 and scaled up throughout the coastal zone of Kobe, with completion of 167 sites by 2024. The city is also planning to implement systems that will automatically close the gates upon receiving early tsunami warnings (Nikkei BP Research Institute 2019).

28 Japan Meteorological Agency Seismic Intensity Scale.

Results: Mitigating Current and Future Flood and Disaster Risks and Preparing the Port and City of Kobe for Them

The storm surge management measures taken in Kobe provide an example of how cities can incrementally work toward mitigating their flood risks in densely urbanized coastal areas by integrating structural and nonstructural measures into their coastal infrastructure development plans and designs, constantly reviewing and enhancing approaches based on thorough reflection on disaster events, and adopting new technologies and solutions. This approach is effective for large-scale storm surge management measures that often require large amounts of space, time, and financing to implement.

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Case 20: Reducing Storm Surge Flood Risk by Raising the Ground Level: Minato Mirai 21 District in Yokohama City

Location:	Minato Mirai 21 (MM21) district is a large, master-planned urban development project in Yokohama City, Kanagawa Prefecture.
Site characteristics:	Minato Mirai 21 district is developed on reclaimed land along Yokohama's waterfront. It serves as a central business district, with various commercial facilities, high-rise office buildings, and tourist spots placed around the harbor. It was developed to connect Yokohama's traditionally important areas with commercial centers of Kannai and the Yokohama Station area.
Flood management measure(s):	
Flood type	Storm surge
Management capacity	Coastal flood management measures in MM21 district, including storm surge floods, are designed based on inundation modeling from the Keichou Earthquake (which occurred in 1605, with an estimated magnitude of 8.5)[a]
Type of measure(s)	Structural (gray)—Ground raising
	Nonstructural—Signage of sea level and evacuation rights, tsunami early warning system, etc.
Relevant entities:	
Implementation	Land readjustment project (approximately 101.8 ha): Urban Renaissance Authority (UR)
	Land reclamation (approximately 73.9 ha): Yokohama City
	Construction of port area: MLIT and Yokohama City
	Construction of street, common tunnel for utility lines (approximately 7 km), sewerage construction, public parks and green space, waste treatment facility, etc.: Yokohama City in partnership with MLIT, UR, private sector, etc.
O&M	Same as above for infrastructure investments
Finance	Same as above
Construction period:	Land readjustment project—1983–2011[b]
Cost:	Estimated total construction and infrastructure investment cost: ¥2.625 trillion ($23.9 billion) from 1983 to 2016, including ¥1.52 trillion for building construction ($13.8 billion) and ¥530 billion for infrastructure construction ($4.8 billion)[b]
Additional benefits and functions:	Urban and economic development
	Establishment of green space and public amenities
	Seismic resilience
	Regional hub for disaster preparedness through establishment of decentralized off-grid energy infrastructure, etc.

Sources:	Urban Development Bureau, Yokohama City 2014, except where otherwise noted.
	a Crisis Management Office, Yokohama City 2013.
	b Some land readjustment projects are ongoing. More information is available in Urban Development Bureau, Yokohama City (2019a and 2019b).

Context: Reclaiming Land for Urban Development

Yokohama City has a long history of reclaiming land along the coast for use as rice fields and residential settlements, going back to the 1700s (Washiyama 2003). Because the inner part of Yokohama City is mostly hilly, ports and industrial factories were built extensively on reclaimed land along the city's waterfront (Yoshioka 2011). Rapid economic development in the 1950s led to the accumulation of population and assets, first in Tokyo and subsequently in Yokohama City. While the city experienced fast population growth and intensive housing development, however, core business units moved to Tokyo.

This led to the development of the **Minato Mirai 21** (MM21) district, starting in 1983, with the purposes of (i) enhancing the economic autonomy of Yokohama City by accumulating commercial enterprises and cultural facilities to attract citizens to work and live there; (ii) transforming previous land uses (for the shipping industry, including as cargo shipyards) into parks and socioculturally vibrant outdoor spaces; and (iii) creating a central business district for the region (Urban Development Bureau, Yokohama City 2014). The MM21 project aimed to connect Yokohama's traditionally important areas with commercial centers of Kannai and the Yokohama Station area.

Given its proximity to the coast, however, the MM21 district faced significant flood and disaster risks from tsunamis, storm surge floods, land subsidence, and soil liquefaction issues. The scale of the proposed project, with a total redevelopment area of 186 ha, housing for more than 10,000 residents, and offices for 190,000 workers, called for the application of both structural and nonstructural measures to ensure security for people living and working close to the bay (Urban Development Bureau, Yokohama City 2014).

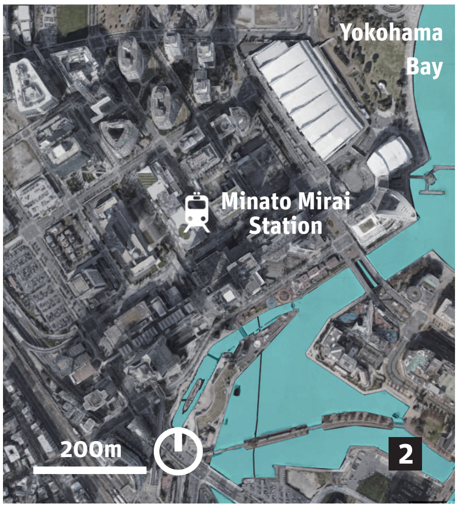

Figure A20.1: Overall View of the Site

Photo Credit: Kenya Endo.

Figure A20.2: Site Context

Source: Google Earth. *Note*: m = meter.

Solution: Investment Design and Key Features

Investment Design

Construction of the MM21 district project was initiated in 1983, based on the large-scale MM21 Master Plan for a 186 ha site along the waterfront of Yokohama. The various components of the development project included 87 ha of residential development, 42 ha for road and rail transportation, 46 ha for parks and green spaces, and 11 ha of port area (Association of Yokohama Minato Mirai 21 2016). The land readjustment project was carried out by the housing developer, Urban Renaissance Authority (UR) between 1983 and 2011, and the new railway station was completed in 2004.

The development project also included land reclamation of a 73.9 ha site, using a sand-drain method for ground stabilizing, and construction of utility corridors beneath arterial roads. Disaster risks, including earthquakes, tsunamis, and storm surge floods, were taken into consideration in the design and implementation of the land reclamation and development.

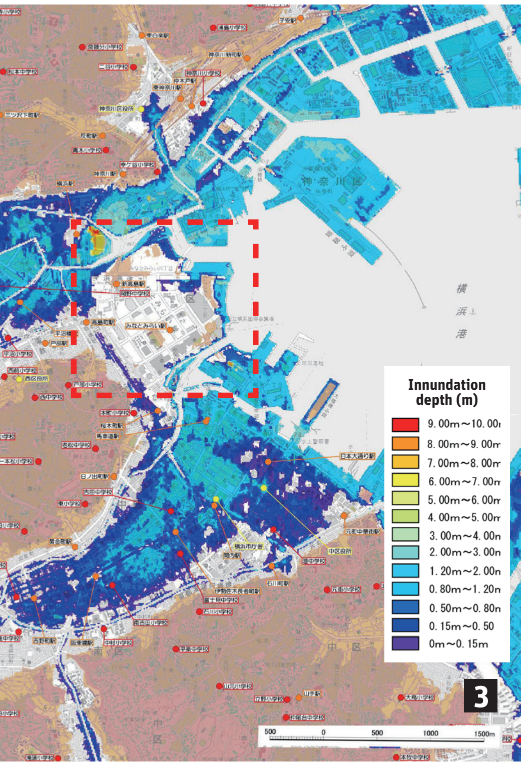

Figure A20.3: Tsunami Flooding Estimation Map

Source: Based on information from Crisis Management Office, Yokohama City (2013).
Note: m = meter.

As measures against tsunamis and storm surges, revetments along the coast were constructed to a height of 2.7–3.1 m above sea level, and residential development in the central districts of MM21 was limited to areas 3.1–5.0 m above sea level (Association of Yokohama Minato Mirai 21 n.d.[b]). These heights were based on inundation modeling from the Keichou Earthquake (which occurred in 1605, with an estimated magnitude of 8.5), as illustrated in the Tsunami Flooding Estimation Map published by Yokohama City (**figure A20.3**).

Key Features

- **Integration of disaster risks from the master planning phase:** From the beginning, the master plan outlined the importance of integrating disaster risk resilience into the basic land and infrastructure development of the MM21 district, particularly against earthquakes, tsunamis, and coastal floods from storm surges. Therefore, the land reclamation, land readjustments, and port development projects were designed and implemented in conjunction with the various disaster risk reduction and preparedness investments mentioned above. The early consideration and integration of risks enabled the development of large-scale, high-cost flood management infrastructure in a highly urbanized area.
- **Combination of hard and soft measures against coastal floods:** Various structural and nonstructural measures for disaster risk management were implemented in recognition of the high vulnerability of a site located on coastal reclaimed land. As described above, MM21 integrates hard measures to prevent and mitigate coastal floods, such as ground raising and coastal revetment construction, as well as soft measures, such as minimum sea level standards for residential development, early warning systems, evacuation signage and awareness raising, and so on (Association of Yokohama Minato Mirai 21 n.d.[c]). Additionally, community-led efforts, such as the Disaster Mitigation Focus Area Management Promotion Committee, established in partnership with the City of Yokohama, created various awareness programs and training sessions to promote safety and disaster resilience initiatives within MM21. The committee launched a program in 2017 that encourages community members and private business owners to offer shelter to people who might face difficulty returning to their homes during emergencies (Association of Yokohama Minato Mirai 21 2017).
- **Establishment of a mechanism to sustain stakeholder collaboration:** In 1984, to facilitate engagement of and coordination among various public, private, civil society, academic, and citizen stakeholders, a general incorporated association called Yokohama Minato Mirai 21 was established. The association took on the responsibility of leading the management of the new area in a cohesive and coordinated manner to ensure the development and sustainability of a livable, environmentally friendly, and culturally vibrant city. As a membership-based organization comprising land and building owners, facility operators, and public authorities, the Yokohama Minato Mirai 21 conducts various projects for the comprehensive management of the area, taking into account the interests of the district's various stakeholders, including the government, workers, companies, institutions, visitors, and citizens, and undertakes various city planning, environmental management,

and cultural promotion initiatives throughout the year. Disaster risk management is a key work area coordinated by the Yokohama Minato Mirai 21, and the association regularly shares information to enhance disaster risk awareness and preparedness of the various MM21 stakeholders (Association of Yokohama Minato Mirai 21 2017).

Results: Economically Vibrant, Disaster-Resilient, and Environmentally Sustainable Urban District

The case project demonstrates how structural and nonstructural storm surge flood measures can be integrated within large-scale coastal redevelopment projects from the design phase to implementation, and how significant economic, environmental, and social benefits can derive from these resilience measures. Despite the high cost and significant time required to develop the MM21 district and ensure its disaster risk resilience, Yokohama City reports significant economic benefits, including the full recovery of an estimated construction investment of ¥2.625 trillion ($23.9 billion) from 1983 until 2016. MM21 attracted more than 1,800 companies and 83 million annual visitors in 2018 alone and generated tax income of more than ¥14.5 billion ($132 million) for the city (Urban Development Bureau, Yokohama City 2019a).

Additionally, by creating an area resilient to seismic activity, tsunamis, and storm surge floods within the urban center of Yokohama, the city was able to enhance its overall disaster risk management capacity. Benefits include the provision of a new evacuation hub with access to disaster-resilient land; utilities, including a decentralized heating and cooling system; ports that can serve as logistics centers for emergency response operations; and an emergency drinking water supply with a storage capacity of 4,500 m^3, which can supply safe drinking water for 500,000 people for three days (Association of Yokohama Minato Mirai 21 n.d.[a]).

Placing a high value on green design, MM21 encouraged public and private investments in developing a green corridor connecting various interventions, such as green roofs and walls and the greening of publicly accessible open spaces, as well as the installation of permeable pavers with cooling effects to alleviate urban flood and heat island effects. Green buildings integrating solar and wind power were also promoted, in line with Yokohama's Environmental Future City initiative (Urban Development Bureau, Yokohama City n.d.).

As a result, despite the high cost of urban development, which is mostly incurred by land reclamation, the site has successfully revitalized the area through rich social and economic activities (**figures A20.4**).

Figure A20.4: Minato Mirai 21 District
Photo Credit: Kenya Endo.

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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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