



Municipal Decision-Making Processes and Learning from Flood Simulation Exercises Using Climate Projections: Insights from Two Municipalities in the Tokachi River Basin, Hokkaido, Japan

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Abstract Climate change is increasing the frequency and intensity of extreme rainfall events, highlighting the limitations of structural flood control measures and the growing importance of evacuation and emergency response. Municipalities play a central role in issuing evacuation information, yet research on their pre-flood decision-making processes and learning remains limited.

This study demonstrates that scenario-based simulation exercises grounded in climate projections can enhance municipal preparedness and adaptive evacuation decisions under climate change, providing empirically grounded evidence based on the experiential learning framework. To this end, we conducted blind-type exercises in two municipalities in the Tokachi River Basin, Hokkaido, Japan, using climate projection data from the d4PDF (Database for Policy Decision Making for Future Climate Change) to design unprecedented flood scenarios. Decision-making processes were systematically recorded and reviewed through post-exercise semi-structured interviews, and analyzed using Kolb's experiential learning model, focusing on concrete experience, reflective observation, and abstract conceptualization.

The results indicated that municipal decision-making followed a sequence of interrelated processes, beginning with precautionary monitoring of typhoon tracks and meteorological warnings, and extending to staff deployment, shelter preparation, and the issuance of evacuation information. While river water levels were decisive for issuing evacuation orders, early precautionary actions based on meteorological forecasts were essential, especially to avoid nighttime evacuations. These findings suggest that simulation exercises for sequential decision-making against unprecedented flood disasters should incorporate comprehensive

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scenarios covering both meteorological conditions and river levels from the early pre-flood stages.

Post-exercise interviews facilitated reflection that transformed experience into learning, enabling officials to identify challenges, generate improvements, and formulate hypotheses for decision-making and preparedness. Key insights were the importance of early preparedness, bold decision-making under uncertainty, and the necessity of monitoring smaller rivers alongside major ones.

Moreover, differences in learning were evident between the municipalities, reflecting differences in exercise scale: in Obihiro, where the simulation was conducted as a risk-management-unit-level exercise, reflections focused primarily on evacuation-information decision-making, whereas in Memuro, where the simulation was conducted as a full-scale municipal exercise, learning extended to broader organizational and field-level operations. Expanding the scale and participation of simulation exercises was found to enhance learning beyond evacuation decisions, extending to field operations and headquarters management.

Keywords: climate change adaptation, extreme rainfall and flood disasters, municipal decision-making for evacuation information, scenario-based simulation exercises, Kolb's experiential learning model

1. INTRODUCTION

1.1 Projections and Adaptation Measures for Heavy Rainfall and Flooding under Climate Change in Japan

The IPCC Sixth Assessment Report (AR6) has evaluated that the warming of the climate system due to greenhouse gas emissions from human activities is unequivocal, leading to increased intensity and frequency of extreme rainfall events and associated flooding (IPCC, 2023). In the report, five future warming scenarios were presented, based on Shared Socioeconomic Pathways (SSPs) that incorporate greenhouse gas emissions and socio-economic development. In the most optimistic scenario, SSP1-1.9 (very low greenhouse gas emissions), which roughly corresponds to a 1.5°C increase in global temperature (similar to the target set by the Paris Agreement adopted in 2015), most major regions on the globe are projected to experience an increase in both the intensity and frequency of heavy rainfall and flooding. At 2°C warming, the magnitude of these changes and the confidence in these projections further increase. Additionally, concerning tropical cyclones, which are one of the primary causes of extreme rainfall and flooding in East Asia including Japan, it is assessed that the proportion of intense tropical cyclones is projected to increase at 1.5°C warming and further increase at 2°C warming.

In Japan, a technical study committee, consisting of government agencies, research institutes, and universities, has quantitatively assessed the regional impact of climate change on rainfall. The projected changes in rainfall across Japan are illustrated in Figure 1 (Technical Study

Committee for Flood Control Plans Considering Climate Change, 2021). Under 2°C global temperature increase since the industrial revolution, which corresponds to approximately SSP1-2.8, the national average change ratio of precipitation for 12-hour or longer durations with an annual exceedance probability of 1/100 is projected to be approximately 1.1 to 1.15 times the current climate (1951–2011), with the frequency of flooding in major rivers (first - class rivers) expected to double. Furthermore, under a 4°C increase, which corresponds to SSP3-7.0, the change ratio for precipitation is projected to be approximately 1.2 to 1.4 times, with short-duration precipitation (3 to 12 hours) increasing by 1.3 to 1.5 times. Consequently, the frequency of flooding in major rivers is projected to quadruple.

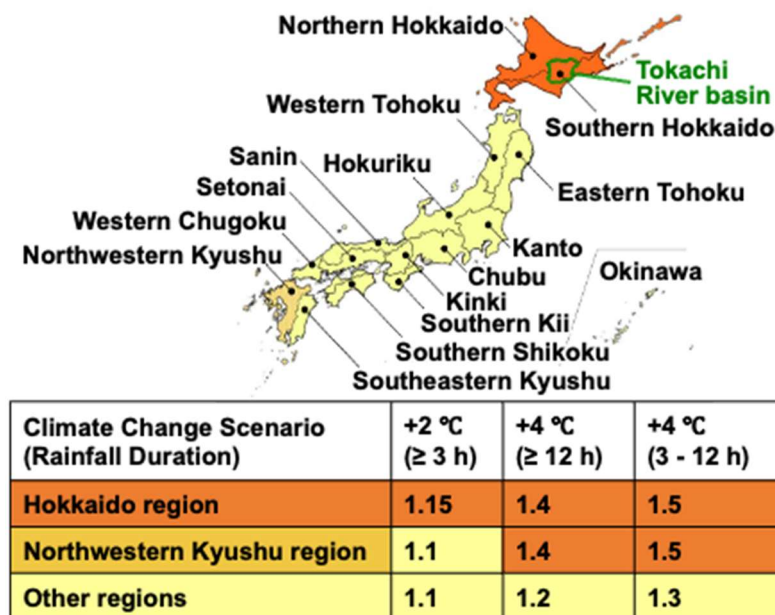


Figure 1. Rainfall change ratio (Cited from the Technical Committee for Flood Control Plans Considering Climate Changes, 2021, with modifications)

Although long-term weather prediction is inherently difficult, the development of a large-ensemble and high-resolution climate projection dataset (Database for Policy Decision Making for Future Climate Change: d4PDF) in Japan has enabled probabilistic assessment of the intensity and frequency of extreme rainfall events and the resulting floods under specific climate states. In this study, the term “climate projection” refers to long-term projections of meteorological variables that incorporate the effects of climate change, as opposed to short-term weather forecasts. It is inherently difficult to predict weather conditions at specific points in long-term forecasts due to the phenomenon known as Lorenz chaos, in which small perturbations amplify over time and lead to significant changes (Lorenz, 1963). However, it has also been suggested that it is still possible to estimate the probability distribution of weather conditions within a given climate state (Lorenz, 1990). The d4PDF is a large climate projection dataset that includes a total of 3,000 years of past climate simulations and 5,400 years of future climate simulations. The past climate simulations cover the period from 1951 to 2011, while the future climate simulations assume a 4°C global temperature increase since the pre-industrial era. These future simulations are based on multiple sea surface temperature (SST) patterns and were generated using a large ensemble approach, in which initial perturbations were applied to produce dozens of simulations under each scenario (Mizuta, 2017). Furthermore, by

dynamically downscaling these global-scale (60 km resolution) climate projections to the Japan region (20 km resolution) and local areas (5 km resolution), it has been confirmed that the reproducibility of localized heavy rainfall events and topographically influenced extreme precipitation has improved (Yamada et al., 2021; Kawase et al., 2023).

In response to the increasing severity of heavy rainfall disasters, the development of large-ensemble climate projections, and the nationwide assessment of precipitation change ratios, Japan has revised its policies and legislation to incorporate climate change considerations into flood risk management. Following the Kanto-Tohoku Heavy Rainfall Event in September 2015, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) promoted the concept of a “Rebuilding Flood-Conscious Societies” emphasizing an integrated approach that acknowledges the limitations of structural flood control measures and the inevitability of large-scale floods that exceed engineering capacities (MLIT, 2015). Additionally, in response to the increasing severity and frequency of water-related disasters due to climate change, MLIT introduced the concept of “River Basin Disaster Resilience and Sustainability by All”, which encourages collaboration among all stakeholders across entire river basins (Koike, 2021). This approach focuses on three main strategies: (1) measures to prevent and reduce flooding, (2) measures to reduce damage to at-risk areas, and (3) measures to mitigate damage and facilitate early recovery and reconstruction. For structural flood control measures corresponding primarily to (1), Japan has shifted from conventional river improvement plans based on exceedance probability flood flow calculations (derived from past observations and typically designed for floods with return periods of 50 to 200 years, depending on river scale) (Nakamura, 2021), toward a framework that incorporates climate projections. In this field, integrated risk assessments that consider probabilities of inundation depth, mortality rates, and damage to residential areas have been increasingly applied in practice (Yamada, 2019). As a non-structural measure primarily corresponding to (2) and (3), the revision of the Flood Control Act in 2021 mandated the creation of flood risk information for all designated Class A and Class B rivers (Flood Control Act, 2021). Additionally, capacity-building for both residents and local governments, including evacuation drills, has been emphasized (e.g., MLIT, 2021).

1.2 Processes Leading to the Issuance of Evacuation Information by Municipalities during Flood Disasters

In Japan, municipalities bear the legal and practical responsibility for non-structural disaster management measures, including the issuance of evacuation information, and their role has become increasingly critical as climate change intensifies, leading to more frequent and severe flood events. The Basic Act on Disaster Management (1991) serves as the cornerstone of Japan’s disaster response framework. Under this law, disaster response is categorized into three major phases: preparedness, emergency response, and recovery. Municipalities, as the primary entities responsible for local disaster management, must implement emergency response measures when a disaster occurs or is imminent. During the initial phase of such responses, municipalities establish a Disaster Response Headquarters composed of municipal officials, based on their Local Disaster Management Plan, which is formulated in accordance with the Basic Act on Disaster Management. This headquarters is responsible for collecting information,

formulating and executing disaster response policies, and issuing evacuation information — a function carried out by the municipal mayor — as well as implementing associated measures such as opening evacuation sites, conducting flood prevention activities, and carrying out rescue operations. In practice, however, flood control and rescue operations are often carried out with the support of other actors, such as fire departments, flood fighting units, or the Self-Defense Forces.

Previous studies analyzing residents' evacuation behavior and its triggers during recent heavy rain disasters suggested that evacuation information was a primary driver of evacuations, aside from the actual occurrence of disasters in their vicinity, direct advisories from neighbors, and other factors (Takeuchi et al., 2022; MLIT, 2019). This indicates that evacuation information plays a crucial role during actual disaster events, as it significantly influences residents' decisions to evacuate.

Focusing mainly on administrative decision-making, Hayashi et al. (2014) conducted a nationwide survey of municipalities with large urban centers to analyze the process leading up to the issuance of evacuation information. Drawing on surveys aligned with regional disaster management plans, they identified four sequential steps: information collection and distribution, development of evacuation information contents, recommendations to the mayor, and dissemination of evacuation information. However, this study was not specific to floods and remained limited to plan analysis. Takanashi and Sakamoto (2019), drawing on post-disaster investigations of heavy rainfall events, argued that delays in issuing evacuation information were linked to failures in information management across multiple tasks — including securing personnel, establishing headquarters, ensuring communication, information collection and dissemination, and coordination within and beyond the organization.

On the other hand, Seki et al. (2016), drawing on detailed records of municipal decision-making in flood disasters, including the issuance of evacuation information, found that decisions integrated both pre-evaluated risks, such as hazard maps, and dynamically updated information from government agencies and experts, rather than relying on pre-evaluated risks alone. Nevertheless, this analysis relied on documentary records, with the rationale for decisions analyzed from objective information. Ushiyama et al. (2003), based on disaster surveys of typhoon events, indicated that municipalities tended to establish a Disaster Response Headquarters early using forecasts and warnings, but to issue evacuation information only after tangible cues such as damage or rising river levels. While valuable, this view remains limited to two phases of decision-making.

Taken together, these studies suggest that municipal decision-making for issuing evacuation and response involves a sequence of interrelated processes rather than a single isolated judgment. It is therefore important to train continuous decision-making, beginning with early information such as forecasts and warnings and progressing by confirming dynamically updated observations like river levels and inundation. At the same time, further accumulation of detailed knowledge on municipal decision-making processes in flood disasters is still needed, as existing studies have often relied mainly on documentary evidence or provided only partial analyses.

1.3 The Necessity for Simulation Exercises and Scenario Design for Unprecedented Flood Situations

The Basic Act on Disaster Management mandates preventive measures to avert or mitigate disasters, including the development of disaster management organizations, training and education, facility improvements, and measures to protect vulnerable populations. While the Act emphasizes training and organizational development, reflecting the significant role of municipal governments in non-structural disaster measures, there remains no well-established methodology for municipal-level flood response exercises—particularly those that systematically incorporate the impacts of climate change.

Iizuka (2020) classified municipal disaster training into two main categories: field training, such as rescue operations and staff mobilization, and table-top exercises. The latter can be further divided into image-training and simulation exercises. Image-training aims to help participants form a general picture of where and how damage might occur, and how organizations or evacuees might behave during a disaster. In contrast, simulation exercises require participants to establish a Disaster Response Headquarters as in an actual disaster, process disaster-related information, discuss response policies, and make decisions. The purpose is not only to simulate disaster situations but also to enhance participants' experience and learning in decision-making. In addition, the concept of blind-type training, in which scenarios are not disclosed to participants in advance, has been recognized as making exercises more practical and realistic. Iizuka also pointed out that while mayors often valued decisiveness and knowledge in disaster officials, practical experience in decision-making and response is essential, along with the direct involvement of mayors as ultimate decision-makers.

With respect to flood-disaster scenarios, Kuwasawa et al. (2008) suggested that visualizing inundation spread and regional conditions enhances understanding of flood phenomena and supports the evaluation of evacuation plans. Katada et al. (2017) expanded this approach by incorporating rainfall data and weather warnings into flood response exercises for municipal officials. This enabled municipal staff to recognize the challenges of issuing evacuation information and the importance of early action. In addition, findings from the exercises revealed that municipal staff were able to respond only in a limited manner once flooding had occurred, highlighting the need to focus on the pre-disaster phase.

Regarding municipal responses to unprecedented flood situations, Sato et al. (2011) noted that situational awareness becomes particularly difficult during unprecedented heavy rainfall events. Yoshida et al. (2021) analyzed decision-making on the issuance of evacuation information across municipalities during past heavy rain events, finding that Evacuation Orders were often delayed under unexpected conditions, such as the rapid escalation of flood risks or hesitation during nighttime. A U.S. Senate Committee report similarly noted that a FEMA-led hurricane simulation exercise conducted prior to Hurricane Katrina proved ineffective, as the scenario conditions used for planning, training, and operational measures were not sufficient to cope with the actual disaster (U.S. Senate Committee on Homeland Security and Governmental Affairs, 2006).

Taken together, these findings underscore that unprecedented flood disaster scenarios under climate change, along with simulation exercise methodologies that enable continuous decision-making by municipal staff, are essential.

1.4 Research Development in Collaboration with Municipalities

In response to these challenges, Suzuki et al. (2023, 2024) developed a simulation exercise methodology for municipal officials that incorporates climate change projections derived from the d4PDF dataset. The method combines rainfall-runoff and flood simulations with river water level data, meteorological advisories, and disaster records, and presents them sequentially in a blind-type format to replicate real-time decision-making conditions. This approach also introduced basin-wide rainfall data and compound flooding from multiple rivers addressing a limitation in Japan where flood risk assessments have traditionally focused on individual rivers, thereby overlooking multi-river risks (Jiang et al., 2013). Climate projection data such as d4PDF are especially valuable because they allow the design of unprecedented and scientifically grounded scenarios beyond the limits of historical records, which are scarce in many municipalities.

The methodology was developed through collaboration with municipalities in Hokkaido between 2020 and 2023. Initial discussions with Obihiro City examined how climate projection data could be incorporated into disaster preparedness. Municipal officials noted that post-flood information could support recovery but was insufficient for real-time emergency decisions, which depend on factors such as disaster prevention plans, predefined river water level thresholds, and rainfall conditions. Resident surveys (Takenouchi et al., 2021) expressed similar concerns. Drawing on records from the 2016 Hokkaido heavy rainfall event, meteorological, hydrological, and flood impact data were compiled, and interviews were conducted with municipal officials responsible for emergency response at the time. These analyses confirmed that multiple information sources—such as rainfall and river warnings, risk forecasts, and large-scale meteorological conditions—are critical for issuing Evacuation Orders and opening shelters, but also highlighted the lack of experience due to the rarity of previous flood events. For instance, in Obihiro City, no evacuation information involving shelter openings had been issued for 35 years prior to 2016.

Building on these findings, Suzuki et al. (2023, 2024) proposed the methodology. The first exercise using this method was conducted in 2022 with staff from the risk management unit of Obihiro City. The approach was later introduced at a workshop organized by MLIT with participation from all 19 municipalities in the Tokachi River Basin. Following the workshop, a request was made by Memuro Town to adopt the framework into its official disaster response training. As a result, the methodology was implemented in Memuro's Disaster Response HQ Setup Training in 2023. This progression reflects both the practical challenges municipalities face in designing scientifically grounded scenarios—which require expertise in meteorology, hydrology, and river management—and the demand for forward-looking methodologies that can support local disaster preparedness.

Obihiro City served as a testbed for developing the methodology, while Memuro Town represented its institutional adoption in municipal disaster management practices. Beyond the proposal itself, there remains a need to analyze the learning derived from these exercises, and to examine how differences in their scale and scope of participation influenced the outcomes.

1.5 Theoretical and Analytical Framework for Sequential Decision-Making and Learning in Simulation Exercises

Kolb's experiential learning model (Kolb, 2014) is a theoretical framework widely applied in professional development and skill acquisition. This model consists of four iterative stages:

- Concrete Experience: engaging directly in new experiences.
- Reflective Observation: reflecting on and analyzing these experiences.
- Abstract Conceptualization: forming concepts and generalizations from the reflections.
- Active Experimentation: applying the newly formed concepts to new situations.

Although similar to the widely used PDCA (Plan-Do-Check-Act) cycle, Kolb's model explicitly incorporates experience acquisition, making it highly compatible with decision-making in simulation exercises. Moreover, the model emphasizes not only the experiential aspect of decision-making during the exercises but also the subsequent stages of reflection and conceptualization (Kolb & Kolb, 2017). Similarly, Kirschenbaum et al. (2023) emphasized that disaster training should not only focus on response actions but also on the decision-making processes themselves.

This study applies the framework to analyze how municipal officials reflect on their own decisions, recognize challenges, and develop new insights that can inform future disaster response.

1.6 Objectives and Structure

In this study, we place emphasis on three aspects: providing concrete experience in decision-making through simulation exercises, analyzing detailed records of these processes, and examining the subsequent stages of reflection and conceptualization through interviews and post-exercise analyses, adopting Kolb's experiential learning model. In this way, the study aims to examine the decision-making processes carried out during the exercises and to analyze the learning derived from them.

This study builds upon the preceding framework in three steps. First, we systematically documented and organized the chronological records of decision-making and situational developments in the simulation exercises. Second, we carried out semi-structured interviews with municipal officials after the exercises to analyze how municipalities made sequential emergency response decisions and to clarify the learning gained through their decision-making. Third, we compared the results from the two municipalities—Obihiro City, where the exercise focused on decisions related to the issuance of evacuation information by

disaster management officials alone, and Memuro Town, where the exercise included the mayor and all municipal staff in cross-departmental response decisions.

The structure of this paper is as follows: Target Municipalities and Disaster Response Framework, Methodology, Results, Discussion, and finally, Conclusion.

2. TARGET MUNICIPALITIES AND DISASTER RESPONSE FRAMEWORK

This chapter provides an overview of the two municipalities where this study was conducted, along with the disaster response framework at the municipal level in Japan as essential background.

2.1 Target Municipalities

This study focuses on Obihiro City and Memuro Town, both located in the Tokachi River Basin in Hokkaido, Japan. The basin experienced the 2016 Hokkaido Heavy Rainfall Event, when four typhoons struck Hokkaido within two weeks.

Figure 2 illustrates the study municipalities, the densely populated urban centers where flood simulations were conducted for simulation exercises, the major river sections managed by MLIT in the basin, the river sections managed by the Hokkaido Prefecture in the municipalities, and the elevation distribution in the Tokachi River Basin. Figure 3 presents (a) the main rivers and water level observatories in Obihiro City and (b) those in Memuro Town, along with the maximum flood inundation depth predicted by MLIT and the Hokkaido Prefecture for a 1-in-1000-year heavy rainfall event (Probable Maximum Flood). The figure also marks the emergency evacuation sites with shelter functions for floods, landmarks such as municipal offices and Japan Railway stations, and densely inhabited districts.

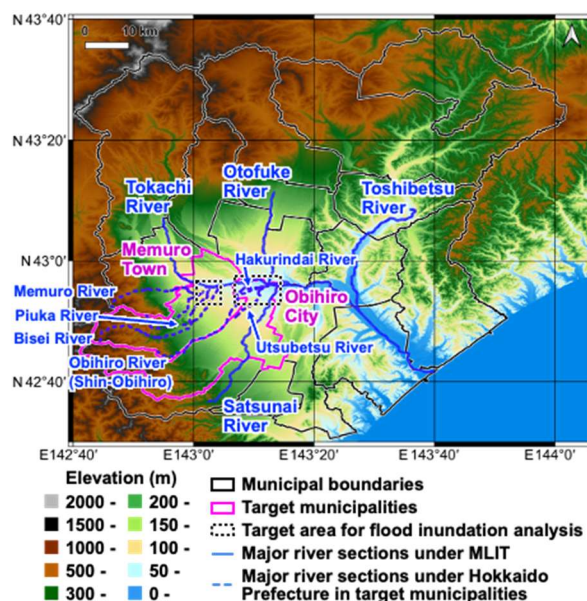


Figure 2. Study area, including urban centers used for flood simulations, key river sections under MLIT and Hokkaido Prefecture management, and the elevation distribution

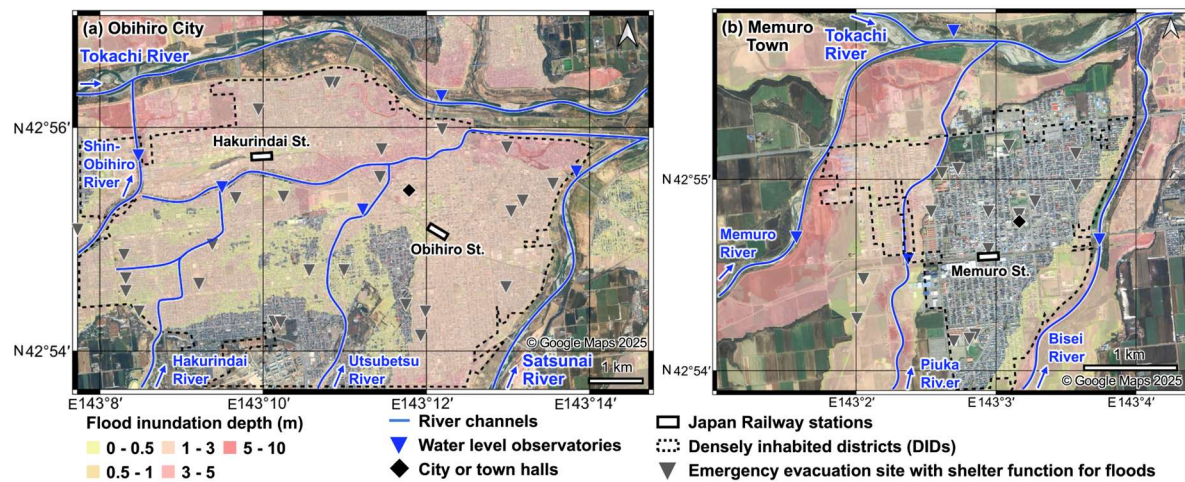


Figure 3. Main rivers and water level observatories, emergency evacuation sites for floods, major landmarks, densely inhabited districts (DIDs), and the estimated maximum flood inundation depth (Probable Maximum Flood) in the target municipalities: (a) Obihiro City, (b) Memuro Town
Note: DIDs are defined by the Statistics Bureau of Japan as contiguous districts with a population density of at least 4,000 persons per km² and a total population of at least 5,000 residents within a municipal boundary.

Obihiro City is situated between the Tokachi River to the north and the Satsunai River to the east. Additionally, the Utsubetsu River, Hakurindai River, and Shin-Obihiro River flow from south to north through the urban area. During the 2016 Hokkaido Heavy Rainfall Event, water levels in the Tokachi and Satsunai Rivers rose significantly, causing embankment failure along a section of the Satsunai River located far from the urban area. In addition, inland flooding occurred within the city itself; however, no severe damage was reported (Japan Society of Civil Engineers Task Force, 2017). Nevertheless, Probable Maximum Flood assessments indicate that the designated flood inundation zones encompass the entire urban area, presenting a high risk of severe flooding. The Tokachi and Satsunai Rivers are protected by large-scale embankments, and areas around the Tokachi River are particularly low-lying, which increases the potential inundation depth in case of embankment failure.

Memuro Town is bordered by the Tokachi River to the north, with the Memuro River and Bisei River flowing from south to north, flanked by the West and East areas, while the Piuka River runs through the urban area from south to north. The town's higher elevation reduces the likelihood that floods from the Tokachi River will reach the urban area. Instead, flood risks are primarily associated with smaller river sections under the jurisdiction of the Hokkaido Prefecture, such as the Memuro River, Piuka River, and Bisei River. In 2016, localized flooding from the Bisei River and urban flooding from the Memuro River occurred, requiring resident evacuations and rescue operations. The highest flood risk area is the low-lying zone between the Memuro and Piuka Rivers, while the central area around the town hall and Japan Railway station is relatively elevated and thus at lower risk, except near the rivers.

A summary of the key geographical, demographic, and institutional characteristics of the two municipalities is presented in Table 1. Obihiro City, being larger in area, population, and staff size, has an independent Risk Management Unit with around 5 to 10 dedicated members.

In contrast, Memuro Town integrates crisis management responsibilities within the General Affairs Division, where a smaller team serves as the core disaster response unit. Due to its larger staff size, municipal-wide simulation exercises in Obihiro City are challenging, and past training has primarily consisted of tabletop exercises using hazard maps. Memuro Town, on the other hand, conducts full-scale simulation exercises involving all employees every few years, although these have primarily targeted earthquake scenarios. In general, Japanese municipal employees rotate between departments approximately every three years rather than being permanently assigned by specialization. However, in both Obihiro City and Memuro Town, some personnel are permanently assigned to crisis management roles, providing a relatively higher level of expertise and experience in disaster management compared to other municipalities.

Table 1. Comparison of Obihiro City and Memuro Town (data from Obihiro City, 2022; Memuro Town, 2023; Statistics Bureau of Japan, 2022)

Municipality	Area (km ²)	Population	DID area (km ²)	Employees	Crisis management structure	Training style	Main perceived flood risks (from 2016 event and Hazard Maps)
Obihiro City	619	166,000	44.1	~1,200	Independent Risk Management Unit (5–10 staff)	Mainly tabletop hazard map exercises	Tokachi & Satsunai Rivers; PMF inundation of entire city
Memuro Town	514	18,000	4.2	~300	Crisis management in General Affairs Division	Full-scale simulation with all staff	Local rivers (Memuro, Piuka, Bisei); localized flooding

2.2 Municipal Disaster Response Framework

The Municipal Disaster Management Plan is formulated at the municipal level (with corresponding versions at the prefectural level) in accordance with the Basic Act on Disaster Management and is aligned with the Basic Disaster Management Plan formulated by the Japan Cabinet Office. The plans in these two municipalities encompass all disaster phases, from prevention to emergency response, recovery, and reconstruction (Obihiro City, 2021; Memuro Town, 2022), and define the key components relevant to this study:

- Municipal Emergency Deployment Status
- Disaster Response Headquarters (HQ)
- Response protocols and roles of HQ and relevant organizations
- Reference criteria for initial emergency response and issuance of evacuation information
- Hazard maps and related risk information (e.g., past disaster records)

The Municipal Emergency Deployment Status consists of five levels for mobilizing municipal staff, ranging from limited standby to full mobilization. Details are provided in Table 2.

Table 2. Municipal emergency deployment status levels

Level	Activation Criteria	Main Actions
Standby 1	Weather or flood warning issued	Information collection begins
Standby 2	Warnings persist, flood risk increases	Key officials summoned for assessment
Emergency 1	Localized flooding expected	Key officials and necessary staff deployed
Emergency 2	Significant disaster forecasted	Majority of municipal staff deployed
Emergency 3	Widespread disaster expected	Full mobilization of all municipal staff

The Disaster Response Headquarters (HQ) is the central body for decision-making and command, activated at higher deployment levels. In practice, some municipalities establish a preliminary Disaster Response HQ with the same organizational structure; for simplicity, this study collectively refers to them as the HQ.

The HQ's response protocols and roles extend to decision-making, evacuation shelter operations, public communication, coordination with related organizations, patrolling, evacuee support, traffic control, and facility management. For operations such as sandbag deployment for flood mitigation or rescue operations for disaster victims, municipalities collaborate with external organizations including police, fire departments, the Self-Defense Forces, construction companies, and prefectural governments.

Evacuation information is issued at the district level within municipalities and follows three levels, which are determined based on river water levels, rainfall, and other reference criteria, and correspond to the categories shown in Table 3. Evacuation of the Elderly, Etc. is issued for those who require additional time to evacuate, whereas Evacuation Orders are directed to all residents in the designated areas, serving as the principal trigger for community-wide evacuation. Finally, at the highest level, Emergency Safety Measures instruct residents to immediately secure their safety as life-threatening conditions are imminent.

Table 3. Alert levels corresponding advisories and warning levels, criteria, evacuation information, and necessary resident actions

Alert level	Heavy rain (inundation) Advisory/ Warning (by JMA)	Flood Risk (by JMA)	Flood Advisory/ Warning (by MLIT)	River water level criteria (by MLIT and prefectures)	Evacuation information (by municipalities)	Necessary actions to be taken by residents
L5	Heavy Rain Emergency Warning	Extreme risk	Information on flooding	High Water Level River flooding	Emergency Safety Assurance	Ensure immediate safety
L4	-	High risk	Information on potential flooding	Hazardous Water Level	Evacuation Order	Evacuate everyone from hazardous areas
L3	Heavy rain warning	Warning	Information to provide a warning on flooding	Evacuation Warning Water Level	Evacuation of the Elderly, Etc.	Elderly and people needing assistance should evacuate
L2	Heavy rain advisory	Caution	Advisory on flooding	Advisory Water Level	-	Confirm necessary evacuation actions
L1	-	-	-	Criteria for Flood Fighting Standby	-	Raise awareness for disaster preparedness

Hazard maps are created by municipalities to show inundation depths under Probable Maximum Flood scenarios, which cover all rivers designated under the Flood Control Act and managed by MLIT or prefectural authorities. These maps also indicate evacuation sites. Hazard maps serve both as a basis for issuing evacuation information and as a tool for public disaster awareness and preparedness.

3. METHODOLOGY

This chapter outlines the following components: the flood disaster scenarios adopted for the simulation exercises, the progression of the exercises and the records of decision-making, as well as the semi-structured interviews conducted in the reflection phase. The initial part of the

methodology follows our earlier studies reported in Suzuki et al. (2023, 2024), while the subsequent parts build upon additional analyses conducted in the present study.

3.1 Flood Disaster Scenarios for the Exercises

To construct the materials for the exercises, we generated meteorological, rainfall, river water level, and flood datasets based on dynamically downscaled climate projection data from the 4°C increase experiments of d4PDF at a 5-km resolution. We then collaborated with municipal officials to select heavy rainfall and flood events, focusing on large-scale rainfall patterns and typhoon tracks that resembled those which had previously caused heavy rain damage in each municipality, but with unprecedented rainfall magnitudes.

The rationale for adopting typhoon tracks similar to past events was that, for both municipalities, these exercises were the first attempts to simulate unprecedented disasters. By selecting scenarios that were partly conceivable based on prior experience while still exceeding previous rainfall magnitudes, participants were able to envision the situations as realistic yet beyond their experience. The methodology of event selection, however, requires further refinement and will be discussed later.

For the selected events, the datasets and the set of information were organized into formats consistent with those used for decision-making during actual flood emergencies, and these were provided in the exercises. For convenience, in this study, we refer to the selected events, the datasets, and the set of information provided in the exercises collectively as a “scenario.”

3.1.1 Events Adopted for the Scenarios

In Obihiro City, we chose a scenario based on a typhoon track similar to Typhoon Lionrock (JMA No. 10), which triggered record-breaking rainfall during the 2016 event. The selected scenario involved flooding from five nearby rivers: the Tokachi, Satsunai, Obihiro, Hakurindai, and Utsubetsu Rivers. This choice reflected the municipality’s need to strengthen preparedness for a flood disaster that could plausibly occur, resembling the destructive typhoon of a decade earlier, but with even more severe impacts.

For Memuro Town, we selected a scenario based on a typhoon track similar to Typhoon Chanthu (JMA No. 7), which became the first typhoon to make landfall in Hokkaido during the 2016 Hokkaido Heavy Rainfall Event and brought substantial rainfall to the area. This scenario was also chosen because flooding would occur primarily from the Memuro and Piuka Rivers, between which lies a district with particularly high inundation risk. Strengthening preparedness for this vulnerable area had been established as the main objective of the 2023 Memuro Town simulation exercise.

These typhoon tracks are illustrated in Figure 4. In addition, Figure 5 shows the maximum inundation depth simulated for each scenario, which generally occurred at the peak of inundation expansion.

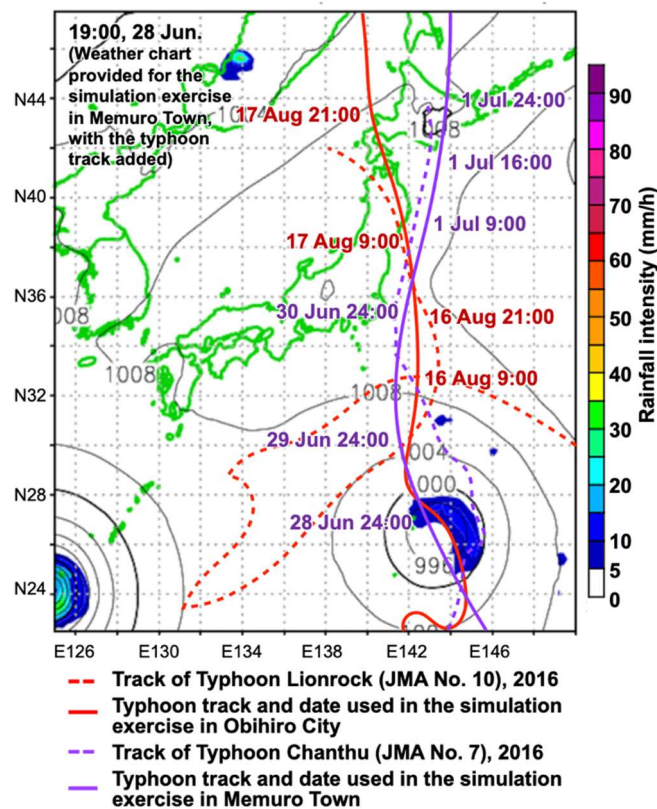


Figure 4. An example of the weather chart used in the exercise, along with the typhoon routes incorporated into the scenarios and the tracks of similar typhoons considered in their selection

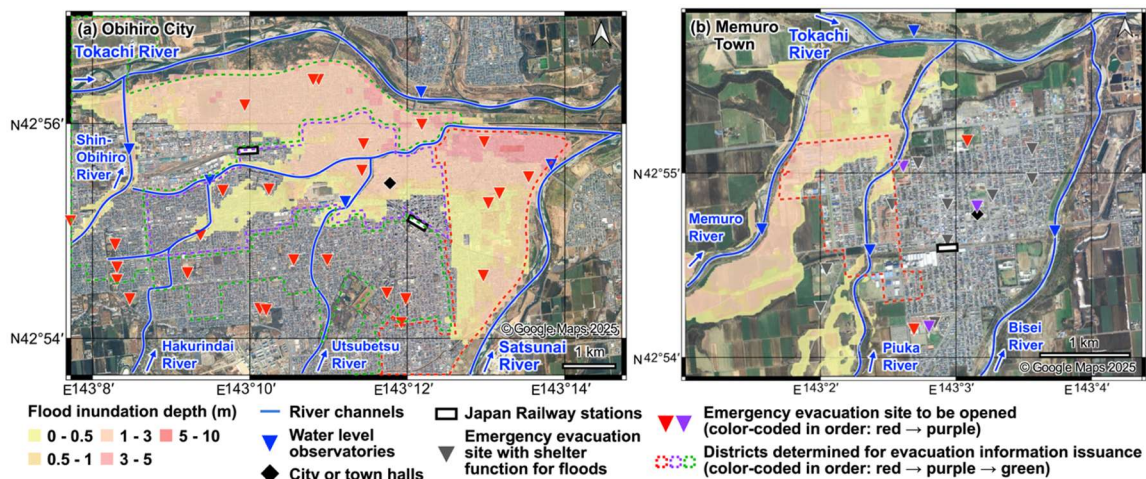


Figure 5. The main rivers and water level observatories, landmarks, emergency evacuation sites with shelter functions for floods, evacuation sites that were decided to be opened during the exercise, areas where evacuation information was issued in the exercise, and the flood inundation depth observed during each scenario at the peak of inundation expansion: (a) Obihiro City on August 17 at 15:00, (b) Memuro Town on June 1 at 16:00

3.1.2 Information Provided in the Simulation Exercises

The information provided in the scenarios primarily consisted of meteorological and river- and flood-related information, including weather charts, short-term rainfall forecasts, river water levels, regional weather announcements and warnings, flood risk based on precipitation,

and river-specific flood warnings. An overview of this information is presented in Table 4, and all information was provided at one-hour intervals. The provision of this information is governed by the River Act, the Flood Control Act, and the Meteorological Service Act, and this terminology follows the JMA multilingual dictionary (JMA, 2024). For simplicity, the term “warning” is used throughout this study to collectively refer to both advisories and warnings. Note that, in actual emergencies, JMA observatories and MLIT/prefectural river offices also provide real-time reference via hotline communication; in this study, official warnings were used as a substitute.

Table 4. Information provided for decision-making in the simulation exercise

Category	Information type	Provider	Reporting scale	Forecast time horizon	Characteristics
Meteorological	Weather charts	JMA	Nationwide, synoptic overview	Several days	Show large-scale weather systems, pressure patterns, and typhoon tracks
	Short-term rainfall forecast	JMA	Nationwide, ~1 km grid resolution	0–6 hours ahead	Provide forecasts of localized heavy rainfall amounts and timing
	Meteorological advisories / warnings	JMA	Regional (prefecture / municipality)	Hours to ~1 day	Issued when heavy rainfall or storm conditions are expected
River & Flood	Water level exceedance information	MLIT / Prefecture	River observation stations	Real-time (instantaneous)	Indicate whether river water levels exceed reference criteria
	Flood risk information	JMA	River sections mainly managed by prefecture	0–3 hours ahead	Spatial forecast of flood risk based on precipitation and runoff estimates
	Flood warning	MLIT	River sections mainly managed by MLIT	4–6 hours ahead (forecast)	Forecast-based warnings indicating high risk of flooding at specific rivers

Figures 4, 5 and 6 show examples of the materials used in the simulation exercises, illustrating the actual format of the information provided to participants. However, meteorological warnings and flood forecasts, which were generally provided as text-based statements indicating levels and regions, are omitted here.

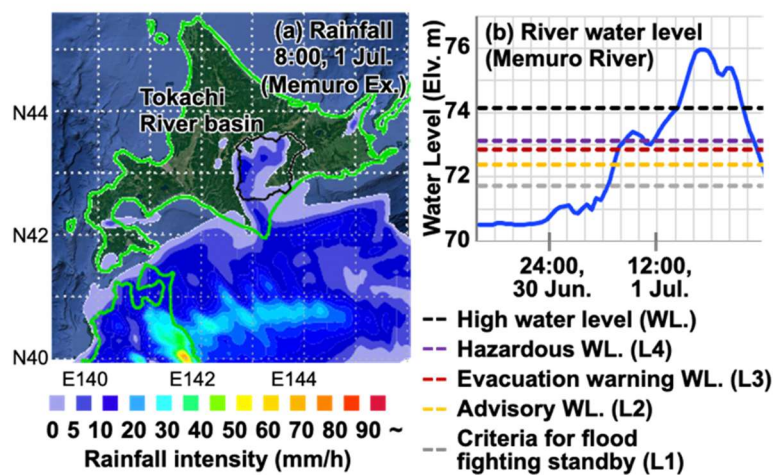


Figure 6. An example of the information provided in the exercise: (a) the Short-Term Rainfall Forecast, (b) the River water levels

Alert levels indicate the urgency of a disaster and are defined by the Japan Cabinet Office (Japan Cabinet Office, 2021). As shown in Table 3, these levels, ranging from L1 to L5, correspond to warning levels issued by JMA and MLIT, are associated with river water level criteria, and serve as the basis for evacuation information issued by municipalities as well as guidance for disaster response actions to be taken by residents. In this study, the corresponding alert level will be referenced rather than the specific warning terminology used by JMA, MLIT, or river offices.

The flow of information delivery during the simulation exercises is summarized in Tables 5 and 6, which present the chronological sequence of different types of information provided to participants. Specifically, the tables include:

Weather information (Tokachi region and broader Japan-wide context):

- Weather and rainfall overview
- Issued weather announcements
- Issued weather warnings

River information (for the target rivers):

- Exceedance status of observed water levels relative to threshold criteria
- Issued flood risk information and flood warnings

By presenting these elements in a time series across the entire scenario, the tables provide an overview of how disaster-related information accumulated and evolved, thereby illustrating the sequential decision-making context faced by municipal officials. This comprehensive scenario outline forms the basis for the analysis of decision-making processes presented in the next chapter.

3.2 The Progression of the Simulation Exercises

A blind-type simulation exercise format was adopted, in which participants were provided with scenario information sequentially, simulating the dynamic development of a flood disaster. Participants were required to make a series of interrelated decisions, including not only the issuance of evacuation information but also the escalation of the emergency deployment levels, responses to emergency developments, and the opening of evacuation shelters. These decisions were made with reference to the Municipal Disaster Management Plan and the operational manuals maintained by each department. Figure 7 presents photographs of the simulation exercises as conducted in each municipality.

In both municipalities, the decision-making processes were systematically recorded in chronological order, as summarized in Tables 5 and 6, and these records served as the primary material for the subsequent analysis presented in the Results chapter. The records included:

- Emergency deployment,
- Municipal staff call-up and deployment,
- Meetings held by the Disaster Response Headquarters,
- Issuance of evacuation information, and
- Decision-making and its rationale, which was reviewed and analyzed through the post-exercise interviews, as presented in the following subsection.

For Memuro Town, in addition to the above, key actions related to emergency response were also documented, as municipal staff participated, which enabled discussions on practical response actions in addition to decision-making. These responses were categorized into three groups: early preparation, evacuation information, and flood-fighting activities.

The detailed situation and setting for the simulation exercise in the two municipalities are described in the following subsections.

Table 5. Timeline of provided information and decision-making in Obihiro City simulation exercise

Date	Time	Decisionmaking and emergency response status in simulation exercises				Weather information Tokachi region and some broader Japan-wide information	River information												
		Emergency deployment	Municipal staff deployment	Held meetings	Evacuation information issuance		Decisionmaking and its rationale by risk management officials	Weather and rain overview	Amn.	Warn.	Obs.	Warn.	Obs.	Warn.	Obs.	Risk	Obs.	Risk	Obs.
14 Aug	1400						• The typhoon, which formed off the eastern coast of the Philippines, reached the Ogasawara Islands, south of Japan, and moved northward.												
	900	Standby Level 1	Risk management officials remain on standby at municipal office	1st risk management officials meeting 2nd risk management officials meeting (with mayor)	(Start of the exercise) -Transition to Standby Level 1, based on weather announcements regarding the typhoon for the Tokachi region. -As the regional-scale rainfall forecast for the next 24 hours exceeds 100mm, a notice is issued to relevant agencies regarding the potential need for response coordination. -Risk management officials collect information, an particular from weather observatory and river management office -Scheduled the next meeting when the next weather announcement will be issued. -Although there is no rainfall, the forecasted 24-hour rainfall remains high, and the typhoon is moving northwest, so vigilance is maintained. -Scheduled the next risk management officials meeting at 15:00, before staff leave work at 17:00, considering the potential need for evacuation shelter setup decisions. -At this stage, the mayor's decision-making becomes necessary, and in an actual disaster situation, the mayor must be summoned to the meeting (although no actual communication has been made).		No.1												
15 Aug	1500	Standby Level 2	Senior managers remain on standby at municipal office	1st emergency executive meeting	-Changed to Standby Level 2, as the situation requires a decision on opening evacuation shelters. -Currently, river water levels are not predicted to rise according to flood forecasts, and the next six hour rainfall forecast remains light. However, the regional-scale rainfall forecast for the next 24 hours is significant, and to avoid nighttime evacuation shelter openings, evacuation orders and activities, the decision was made to open evacuation shelters. -To ensure early movement to safer locations, not only evacuation shelters within the hazard map flood zones but also nearby shelters will be opened. -As the current water level does not warrant an evacuation order, a public announcement will be prepared to encourage voluntary evacuation. -As the atmospheric pressure continues to drop, the typhoon is expected to intensify, and confirming that rainfall will begin on the upstream side of the Hida Mountains in Oshima City within the next six hours. Emergency Level 1 is declared due to the increasing risk. -Given the significant regional-scale rainfall forecast for the next 24 hours and the need to avoid nighttime evacuation, an announcement for voluntary evacuation is issued for residents near the Satsuna area (Area red-coded in Fig. 7(a)). -Requested preparation from flood-fighting units, related organizations, and cooperating companies involved in flood-fighting activities. -Expected river water levels to rise within the next six hours based on the rainfall forecast, requested preparation from sluice gate operators. -Scheduled the next meeting for when flood forecasts or flood risks indicate that any river is likely to exceed the L3 reference water level (with a high probability for the Satsuna River).		No.3												
	2100	Emergency Level 1	Essential staff report to the municipal office	3rd emergency executive meeting	-Satsuna River water level exceeded L1, and weather conditions are not expected to improve. Due to nighttime conditions requiring early decisions, an evacuation advisory for the elderly is issued to residents near the Satsuna area (Area red-coded in Fig. 7(a)). -Requested preparation from flood-fighting units, related organizations, and cooperating companies involved in flood-fighting activities. -Expected river water levels to rise within the next six hours based on the rainfall forecast, requested preparation from sluice gate operators. -Scheduled the next meeting for when flood forecasts or flood risks indicate that any river is likely to exceed the L3 reference water level (with a high probability for the Satsuna River).														
16 Aug	2300																		
	1800			2nd emergency executive meeting	L3: Evacuation order (Area red-coded in Fig. 7(a)) -Issued evacuation orders to residents near the Satsuna River and Utsunubiki River as water levels exceeded L3 and weather conditions are not expected to improve. Due to nighttime conditions requiring early decisions, an evacuation advisory for the elderly is issued to residents near the Satsuna area (Area red-coded in Fig. 7(a)). -Requested preparation from flood-fighting units, related organizations, and cooperating companies involved in flood-fighting activities. -Expected river water levels to rise within the next six hours based on the rainfall forecast, requested preparation from sluice gate operators. -Scheduled the next meeting for when flood forecasts or flood risks indicate that any river is likely to exceed the L3 reference water level (with a high probability for the Satsuna River).														
2400				1st disaster response HQ meeting	L4: Evacuation order (Area red-coded in Fig. 7(a)) -Upgraded the evacuation advisory for the elderly issued for the Satsuna River to a full evacuation order (Area red-coded in Fig. 7(a)). -Scheduled the next disaster response coordination meeting in one hour.	No.4													
	1000	Emergency Level 3 (Level 2): Disaster response HQ setup	All staff report to the municipal office	2nd disaster response HQ meeting 3rd disaster response HQ meeting	-Employed patrols for damage and risk assessment as multiple rivers are forecasted to have increased flood risks. -Initiated sluice gate operations and associated pump drainage. -Since evacuation information has been widely issued, flood-fighting activities and evacuation information transmission will continue until the next warning is issued. -Issued an emergency safety assurance order for the entire city due to the L5 weather warning. -Scheduled the next disaster response headquarters meeting in one hour.														
17 Aug	600			4th disaster response HQ meeting	L5: Ensure immediate safety (entire city area) -Following the occurrence of flooding, strengthened evacuation support, damage assessment patrols, and flood-fighting activities. -Confirmed resident safety at dawn. -Continued flood-fighting activities and information gathering for the next two hours.														
	800			5th disaster response HQ meeting	-Transmitted updated evacuation information status at dawn.														
1000					(End of the exercise) -Review the progression of the situation and damage after the exercise.														
	1100																		
1500																			
Outside the exercise period																			

Table 6. Timeline of provided information and decision-making in Memuro Town simulation exercise

Decision-making and emergency response status in simulation exercises										Weather information				River information			
Date	Time	Emergency deployment	Municipal staff deployment	Held meetings	Evacuation information issuance	Decision-making and its rationale by risk management officials and emergency headquarters	Key actions related to emergency response, based on decision-making		Tokachi region and some broader Japan-wide information	Weather and rain overview	Ann.	Warn.	Obs.	Tokachi River	Memuro River	Pulka River	Bisei River
27 Jun	15:00			1st emergency executive meeting		-Transition to Standby Level 1, based on expected typhoon path from weather charts and weather announcements -The next meeting was scheduled based on the typhoon's and weather conditions.	-Risk management officials initiated information collection (Early preparation) -Senior managers exchange updates		-A typhoon formed east of the Philippines								
28 Jun	10:00	Standby Level 1	management officials remain on standby at home or municipal office	2nd emergency executive meeting		-Intensely proffer information gathering considering the typhoon's approach to Japan and the expected path -As the 24-hour rainfall forecast remained high and the typhoon was predicted to approach, another meeting was held. -A follow-up meeting was scheduled for the evening. -Consider Standby Level 2, depending on the next weather announcement, based on expected path and the expected issuance of advisories and warnings	(Early preparation) -Prepare for the establishment of the disaster response HQ and notify staff design coordination with relevant organizations for emergency response, including evacuation site setup, evacuation orders, rescue operations, and flood-fighting activities		-The typhoon reached the Ogasawara Islands, south of Japan, and moved northwest	No.1							
30 Jun	15:00			3rd emergency executive meeting		-Transition to Standby Level 2, based on the weather announcement and the potential for heavy rainfall -Schedule the disaster response HQ meeting and acquire senior managers and essential staff to report to the municipal office at 8:00 AM on June 30	(Early preparation) -Prepare for the establishment of the disaster response HQ and notify staff design coordination with relevant organizations for emergency response, including evacuation site setup, evacuation orders, rescue operations, and flood-fighting activities		-The typhoon moved northwest, passing southeast of the Boso Peninsula in the Kanto region	No.2							
	17:00	Standby Level 2	Senior managers remain on standby at home or municipal office	3rd emergency executive meeting		-Transition to Standby Level 2, based on the weather announcement and the potential for heavy rainfall -Schedule the disaster response HQ meeting and acquire senior managers and essential staff to report to the municipal office at 8:00 AM on June 30	(Early preparation) -Prepare evacuation shelters and transport supplies (begin accepting evacuees upon completion) -Issue evacuation advisory for the elderly and others -Disseminate evacuation orders via SNS, email, personal communication devices, and public information displays -Coordinate media response related to the issuance of evacuation orders -Notify neighborhood associations and community disaster prevention organizations -Prepare for safety confirmation in evacuation order areas -Issue emergency notices to schools, hospitals, railway companies, and other businesses -Coordinate school closures with the board of education -Request patrol support from cooperating construction companies -Coordinate the acceptance of support from the Self-Defense Forces -Prepare flood-fighting materials -Coordinate with personnel responsible for sluice gates and pump operations -Issue and disseminate evacuation orders -Prepare for the establishment of additional evacuation shelters -Coordinate media response related to the issuance of evacuation orders -Coordinate full-scale damage assessments in assigned areas -Begin partial placement of sandbags for flood protection -Prepare for road closures in some areas due to the issuance of evacuation orders -Notify public facilities regarding usage restrictions		-Light rain began in the Tokachi River basin due to the typhoon's outer rainbands -The typhoon was moving north along the coast of Iwate Prefecture in the Tohoku region	No.3							
	7:30																
	8:00	Emergency Level 2 (skiped 1st disaster response HQ meeting in the municipal HQ setup	Senior managers and essential staff report to the municipal office	1st disaster response HQ meeting	L3: Evacuation order for elderly and essential staff (Area red-coded in Fig.7 (b))	(Start of the exercise at the municipal office) -Issue evacuation order for the elderly and others for the east side of the Memuro River (including, as a precaution, the low-lying area up to the west side of the Pulka River), based on the Memuro River water level exceeding L3, weather conditions, flood risk, and rainfall forecast (Area red-coded in Fig.7 (b)) -Coordinate evacuation shelters (Area red-coded in Fig.7 (b)) -All staff assemble and call up the flood-fighting unit in response to the approaching rainfall area, forecasted conditions, and rising river levels -Deploy patrols for situation and risk investigation -Schedule the next HQ meeting in one hour	(Regarding evacuation information) -Issue and disseminate evacuation orders -Request patrol support from cooperating construction companies -Coordinate the acceptance of support from the Self-Defense Forces -Prepare flood-fighting materials -Coordinate with personnel responsible for sluice gates and pump operations -Issue and disseminate evacuation orders -Prepare for the establishment of additional evacuation shelters -Coordinate media response related to the issuance of evacuation orders -Coordinate full-scale damage assessments in assigned areas -Begin partial placement of sandbags for flood protection -Prepare for road closures in some areas due to the issuance of evacuation orders -Notify public facilities regarding usage restrictions		-The northern heavy rainfall zone of the typhoon approached Cape Erimo, south of the Tokachi River basin								
1 Jul	9:00		All staff report to the municipal office	2nd disaster response HQ meeting	L4: Evacuation order for all staff (Area red-coded in Fig.7 (b))	-Issue evacuation order based on the Memuro River water level exceeding L3, along with the rate of water level rise and rainfall forecast (Area red-coded in Fig.7 (b)) -Request support for rescue and flood-fighting activities from the Self-Defense Forces and partner companies -Enhance flood-fighting activities -Schedule the next HQ meeting in one hour	(Regarding evacuation information) -Issue and disseminate evacuation orders -Request for the establishment of additional evacuation shelters -Coordinate media response related to the issuance of evacuation orders -Coordinate full-scale damage assessments in assigned areas -Begin partial placement of sandbags for flood protection -Prepare for road closures in some areas due to the issuance of evacuation orders -Notify public facilities regarding usage restrictions		-A heavy rainfall zone began to cover the eastern slopes of the Hidaiki Mountains, upstream of Memuro Town	No.4							
	10:00	Emergency Level 3		3rd disaster response HQ meeting		-Open additional evacuation shelters (Area purple-coded in Fig.7 (b)) -Enhance patrols for situation and risk investigation due to intensified rainfall	(Regarding flood-fighting activities) -Request for the deployment of flood-fighting units and equipment (e.g., underpasses expected to flood) -Deploy additional sandbags for flood protection										
	11:00			4th disaster response HQ meeting		(End of the exercise) -Review the progression of the situation and damage after the exercise	(End of the exercise - expected responses) -Continue assessing damage and collecting information -Continue ongoing support for resident evacuations -Request additional rescue operations and implement road closures as necessary				No.5						
12:00											No.6						
13:00																	
14:00																	
15:00																	
16:00																	

3.2.1 Obihiro City

In Obihiro City, the simulation exercise emphasized strategic, hours–days decision-making by disaster risk management officials rather than the real-time progression of events. The timing of discussions and the scheduling of meetings were determined based on the warnings and situational updates provided, enabling participants to engage in concentrated deliberation on critical emergency response measures.

As a result, approximately 24 hours of emergency response decision-making was condensed into a three-hour session. To facilitate the exercise, the relevant information was displayed on a large screen in the Disaster Response Headquarters (HQ) meeting room, with scenario updates provided at the appropriate times to prompt discussion.

3.2.2 Memuro Town

In contrast, the simulation exercise in Memuro Town emphasized not only decision-making but also the operational responses of municipal staff. The scenario progressed in real time, and participants determined when to convene the next HQ meeting based on situational developments. This structure resulted in a series of meetings and decision-making processes that closely mirrored actual emergency management operations.

The municipal office-based exercise lasted approximately four hours. However, risk management officials and senior managers had already begun receiving situational updates — such as weather charts and weather announcements — three days in advance via an online information-sharing system. Key preparatory decisions, including the timing of emergency deployment, the convening of executive meetings, the initiation of information-gathering, and the mobilization of staff, were therefore made prior to the commencement of the official office-based exercise.

During the exercise itself, information was delivered in two ways: directly to risk management officials and senior managers as well as other municipal staff with access to the online system, and visually to all HQ participants through a screen display in the municipal Disaster Response Headquarters meeting room.



Figure 7. Photographs of the simulation exercises

3.3 Post-Exercise Semi-Structured Interviews for Analysis of Decision-Making Processes and Learning

This study conducted post-exercise semi-structured interviews to review the decision-making processes carried out during the exercises and to analyze the learning derived from them through collaborative reflection with participants. The interviews were structured on the basis of Kolb's experiential learning model (Kolb, 2014), which comprises four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. In this study, the interviews addressed the first three stages, while active experimentation was not directly covered; instead, it corresponds to subsequent simulation exercises or actual future disaster responses. Here, concrete experience corresponds to decision-making during the exercises when facing unprecedented flood disaster situations; reflective observation to the chronological review of scenarios and decision-making through post-exercise interviews; and abstract conceptualization to the development of insights and learning for future disaster responses based on reflection. Insights refer to the identification of successful practices and challenges encountered, while learning refers to the construction of hypotheses and consideration of improvement measures that could inform future practice.

The interviews were broadly divided into two parts:

- Review of decision-making processes: Each phase of the exercise was reviewed in chronological order to analyze the reasoning behind the decisions. In addition, discussions also addressed the sequence of processes deemed necessary to reach the final issuance of evacuation information. The review made use of the scenario outlines and decision-making summarized in Tables 5 and 6. These findings, organized based on exercise records and participants' comments, are presented in the section on decision-making and its rationales. This review provided the basis for reflective observation on the concrete experience in the exercises.
- Development of insights and learning: Participants were also asked to reflect on their experiences during both the exercise and the review, focusing on insights related to decision-making, organizational structures, and operational management, and on the learning derived from these reflections. They discussed successful practices, difficulties encountered, and areas for improvement. This reflection provided the basis for abstract conceptualization.

For Memuro Town, reflections also incorporated inputs from HQ members and other municipal staff that were indirectly gathered through crisis management officials and organized during the review.

Furthermore, a comparative analysis of exercises at different scales and participants will be discussed based on these interview results.

4. RESULT

This chapter presents the results of the simulation exercises and post-exercise interviews, focusing first on the decisions made and their rationales, and then on the insights and learning identified as findings.

4.1 Decision-Making Processes and Rationales

4.1.1 Result of Obihiro City

On August 16 at 9:00, the first risk management officials meeting was held following the transition to Standby Level 1, based on weather announcements concerning the approaching typhoon in Japan. As the regional-scale 24-hour rainfall forecast exceeded 100 mm, a notice was issued to relevant agencies to alert them to the potential need for response coordination. Risk management officials began collecting information, particularly from the weather observatory and river management office. The next meeting was scheduled to coincide with the release of the next weather announcement. Risk management officials remained on standby at the municipal office.

At 15:00, the first emergency executive meeting was held, and the status was elevated to Standby Level 2 due to the necessity of deciding whether to open evacuation sites. While flood forecasts did not indicate an immediate rise in river water levels and the six-hour rainfall forecast remained relatively light, the regional-scale 24-hour rainfall forecast was substantial. To avoid the difficulties associated with nighttime evacuation site openings, evacuation information, and related activities, the decision was made to open evacuation sites in advance. Not only evacuation sites within hazard map flood zones but also nearby sites were included to facilitate early movement to safer locations. Since river water levels at that point did not necessitate an evacuation information, a public announcement was prepared to encourage voluntary evacuation. Senior managers remained on standby at the municipal office.

At 18:00, the second emergency executive meeting was conducted following the latest weather announcements. As the atmospheric pressure continued to drop, the typhoon was expected to intensify. Given forecasts indicating that rainfall would begin on the upstream side of the Hidaka Mountains within the next six hours, Emergency Level 1 was declared due to the increasing risk. Considering the significant regional-scale rainfall forecast for the next 24 hours and the aim to avoid nighttime evacuations, a voluntary evacuation announcement was issued for residents living near urban rivers. The next meeting was scheduled for the moment when any river exceeded its reference water level. Essential staff reported to the municipal office.

At 21:00, the third emergency executive meeting was held as the water level of the Satsunai River exceeded L1, with no expectation of immediate improvement in weather conditions. Given the need for early nighttime decision-making, Evacuation of the Elderly, Etc. was issued to residents near the Satsunai area. Additionally, flood-fighting units, related organizations, and cooperating companies involved in flood-fighting activities were requested to prepare for

deployment. Anticipating further increases in river water levels within the next six hours based on rainfall forecasts, sluice gate operators were also placed on standby. The next meeting was scheduled for when flood forecasts or flood risks indicated that any river was likely to exceed the L3 reference water level, with particular concern for the Satsunai River.

At 24:00, the first disaster response headquarters meeting was convened. Due to the rapid escalation of the situation, Emergency Level 3 was declared, skipping Level 2, and the Disaster Response HQ was officially established. Evacuation Orders were issued to residents near the Satsunai River and Utsubetsu River, as both water levels exceeded L3 and weather warnings also reached L3, indicating worsening conditions. The weather announcement forecasted over 200 mm of regional-scale rainfall for the next 24 hours, an unprecedented amount. In response, the Evacuation Order was extended to a broader area, including the vicinity of the Tokachi River. Evacuation of the Elderly, Etc. near the Satsunai River was upgraded to a Evacuation Order. All municipal staff were instructed to report to the municipal office and next meeting was scheduled for the following hour.

At 1:00 on August 17, the second disaster response headquarters meeting was held. Patrols were deployed to assess damage and flood risk, as multiple rivers were forecasted to experience increasing flood risks. Sluice gate operations and associated pump drainage were initiated. Since evacuation information had already been widely disseminated, flood-fighting activities and the transmission of evacuation information were set to continue until further warnings were issued.

At 5:00, the third disaster response headquarters meeting took place. In response to the L5 weather warning, an Emergency Safety Measures was issued for the entire city. The next disaster response headquarters meeting was scheduled for the following hour.

At 6:00, during the fourth disaster response headquarters meeting, as flooding had already occurred, efforts were intensified to support evacuations, conduct damage assessment patrols, and reinforce flood-fighting activities. Resident safety was confirmed at dawn, and flood-fighting activities and information collection continued for the next two hours.

At 8:00, the fifth disaster response headquarters meeting was held, and an updated evacuation information status was transmitted at dawn.

At 10:00, the exercise concluded with a review of the situation's progression and a damage assessment.

4.1.2 Result of Memuro Town

On June 27 at 15:00, following the formation of the typhoon, risk management officials initiated information collection as early preparation.

On June 28 at 10:00, The first emergency executive meeting was held, marking the transition to Standby Level 1. This decision was based on the expected typhoon path, as indicated by weather charts and announcements. The next meeting was scheduled in accordance with the evolving typhoon track and weather conditions. As part of the early preparation responses, risk

management officials continued to collect information, while senior managers exchanged updates to ensure preparedness.

On June 30 at 08:00, the second emergency executive meeting was convened, still under Standby Level 1. With the typhoon approaching Japan and the 24-hour rainfall forecast remaining high, priority was placed on intensified information gathering. Early preparation at this stage included continuous monitoring and information exchange, and another meeting was scheduled for the evening.

At 15:00 on the same day, a consultation with the deputy mayor was held to consider the possibility of activating emergency response. During this discussion, the potential transition to Standby Level 2 was raised, depending on the next weather announcement. This consideration was informed by the expected typhoon path and the anticipated issuance of advisories and warnings.

At 17:00, the third emergency executive meeting was held, and the transition to Standby Level 2 was decided based on the latest weather announcement and the increasing risk of heavy rainfall. It was determined that the disaster response headquarters (HQ) should be established, with the first HQ meeting scheduled for the following morning. Senior managers and essential staff were instructed to report to the municipal office by 08:00. In preparation for potential emergency operations, steps were taken to organize the disaster response HQ, notify staff, and initiate coordination with relevant organizations. These preparations included readiness for opening evacuation sites, issuing evacuation information, arranging rescue operations, and planning flood-fighting activities by the responsible municipal divisions.

On July 1 at 08:00, the first disaster response HQ meeting was convened under Emergency Level 2, marking the official start of the exercise at the municipal office. Notably, risk management officials had already been on standby at the municipal office one hour prior to the meeting. At this time, Evacuation of the Elderly, Etc. was issued for the east side of the Memuro River, extending as a precaution to low-lying areas on the west side of the Piuka River. This decision was based on the Memuro River water level exceeding L3, alongside unfavorable weather conditions and rainfall forecasts. The inclusion of the Piuka River's west side was decided because participants noted its rapid water-level fluctuations as a small catchment, its adjacency to the Memuro River basin, and the fact that the area between the Memuro and Piuka Rivers is geographically and socially regarded as a single integrated district. It was also decided that the next HQ meeting would be held within one hour. Consequently, the disaster response HQ was formally established, and preparations were made for opening evacuation sites. Given the limited availability of personnel and the time constraints associated with issuing evacuation information, the municipality prioritized the opening of large-scale shelters. At the same time, it was decided that all municipal staff would report for duty and that the flood-fighting unit would be called up. Patrols were deployed to monitor the situation and conduct risk assessments, while coordination was established with personnel responsible for sluice gates and pump operations, and flood-fighting materials were prepared. Evacuation-related measures included the preparation of shelters, delivery of supplies, and arrangements to begin accepting evacuees as soon as setup was completed. Evacuation of the Elderly, Etc. was issued and

disseminated via social media, email, personal communication devices, and public announcement vehicles. Additional efforts were made to coordinate media responses regarding evacuation information, notify neighborhood associations and community disaster prevention organizations, and prepare for safety confirmation in evacuation information areas. Emergency notices were also issued to schools, hospitals, railway companies, and businesses, while coordination with the board of education led to school closures. Furthermore, the municipality considered issuing evacuation requests to tourist facilities, including local campgrounds.

At 09:00, the second disaster response HQ meeting was held, during which the municipality transitioned to Emergency Level 3. An Evacuation Order was issued for areas near the Memuro River, as its water level had exceeded L3, together with an increased flood risk reaching L4. At this time, the municipality, anticipating both an expansion of risk and an increase in evacuees, considered opening additional shelters and decided to request support for rescue and flood-fighting activities from the Self-Defense Forces and partner companies. It was also decided that the next HQ meeting would be held within one hour. In addition, Evacuation Orders were disseminated, evacuees began to be accepted at designated shelters, and preparations were made for the establishment of additional shelters. Businesses were notified about the evacuation orders, and the media response regarding the issuance of evacuation information was coordinated. With respect to flood-fighting activities, full-scale damage assessments were initiated in assigned areas, sandbags were partially deployed for flood protection, and preparations were made for road closures in Evacuation Order zones. Public facilities were also notified regarding usage restrictions.

At 10:00, the third disaster response HQ meeting took place, with Emergency Level 3 maintained. Additional evacuation shelters were opened, and patrols were enhanced to monitor risks as rainfall intensified. Since Evacuation Orders had already been issued across a wide area, there were fewer urgent decisions to be made at this stage. Participants nevertheless emphasized that in an actual disaster, continuous monitoring and information gathering would be essential, along with ongoing support for evacuations and flood-fighting operations. They further noted that such efforts would need to be prioritized according to high-risk areas and reported damages to ensure a proactive response to evolving conditions. At this time, evacuees began to be accepted at the newly opened shelters, patrols were strengthened throughout the municipality, and road closures were implemented in Evacuation Order areas and other vulnerable sites such as underpasses expected to flood. Additional sandbags were also deployed for flood protection.

At 11:00, the fourth disaster response HQ meeting was convened. The HQ continued to assess damage and collect information, considered the need for ongoing support of resident evacuations, and requested additional rescue operations where necessary. Road closures were also implemented as conditions required. A review of the overall progression of the situation and associated damages was conducted, marking the conclusion of the exercise.

4.1.3 Necessary Processes for Issuing Evacuation Information

Based on the results of both municipalities, the sequence of processes necessary to issue evacuation information was generally consistent. These included:

- Initiation of precautionary monitoring and continuous information gathering
- Adjustment of emergency deployment status to initiate HQ operations
- Establishment of the Disaster Response Headquarters (HQ) to oversee decision-making and staff mobilization
- Deployment of staff to open and manage evacuation sites and to carry out information dissemination related to shelter operations
- Preparation of public announcement vehicles and other methods for disseminating evacuation information
- Consultation with the final decision-makers, such as the mayor

These processes were not strictly linear but represented the minimum set required to enable the issuance of evacuation information, with some of them being carried out in parallel. The time required for each process varied depending on the situation. For example, if a larger number of evacuation sites needed to be opened, additional staff would be required, resulting in longer preparation times. In addition, participants emphasized that during nighttime, contacting, coordinating, and mobilizing staff was noted to take significantly more time at night.

4.2 Insights and Learning

4.2.1 Findings from Obihiro City

An important insight from the simulation in Obihiro was that the decision to call in staff for standby preparation as the typhoon approached and the 24-hour rainfall forecast increased was effective. Participants considered successful the early and extensive opening of evacuation sites before sunset, and the issuance of evacuation information not only for areas directly surrounding rising rivers but also for a wider area based on rainfall forecasts.

However, the exercise also revealed several challenges. It was not initially expected that flooding would occur across such a wide area. In particular, while the initial focus was on major rivers such as the Satsunai, which had experienced damage in recent years, the actual flooding occurred due to the rapid rise in water levels of smaller rivers that were not under close watch. This highlighted the necessity of monitoring smaller rivers as well as major rivers, whose rapid rises may cause unexpected flooding, particularly under the influence of climate change. At the same time, it was suggested that, because smaller rivers generally have less detailed forecasting, municipal officials may face difficult judgment. To ensure evacuations before nightfall, a series of preparatory processes were necessary, including early communication, evacuation site setup, securing personnel, and prior consultations among decision-makers. As a result, before substantial rainfall had begun, bold decisions had to be made primarily on meteorological forecasts, which are inherently less certain than river levels.

These reflections reinforced an implicit hypothesis that, if heavy rainfall is expected to continue through the night, not only river water levels but also weather charts and rainfall forecasts should be monitored at an earlier stage to avoid missing the critical timing for issuing evacuation information and preparatory actions. In addition, in the face of unprecedented typhoons or extreme rainfall, municipalities will need not only to adhere to established guidelines but also to make flexible and adaptive decisions.

Finally, it was noted that some of the bold decisions in this exercise were facilitated by the simulation setting itself; in a real disaster, similar decisions might not be taken due to the risk of public criticism. The reflection underscored the importance of issuing evacuation information without hesitation, despite potential concerns about criticism, in order to safeguard residents' safety.

4.2.2 Findings from Memuro Town

Overall, the reflections in Memuro Town placed emphasis not only on decision-making but also on the concrete aspects of field-level responses and HQ management.

In the exercise, a series of decisions and actions were made or assumed: issuing early warnings, coordinating with decision-makers and relevant organizations, preparing shelters and personnel, issuing evacuation information, and carrying out flood-fighting activities. A successful decision was to issue evacuation information not only for the Memuro River, where water levels were rising, but also for the Piuka River area, where flood risks were high and rainfall impacts were expected to be similar. In opening shelters, priority was given to large facilities, taking into account staffing limitations. In terms of preparedness, several responses were undertaken, including the early initiation of precautionary measures following typhoon development, thorough information gathering, coordination with relevant agencies, concrete arrangements for shelter operations, prioritization of tasks, media response, and requests for support from external organizations. Participants also highlighted that whiteboards were useful for real-time integration of HQ decisions and departmental responses.

However, several challenges and areas for improvement were also identified. These reflections can be grouped into three main areas: decision-making, field-level responses and HQ management.

- **Decision-making:** Since small and medium-sized rivers—the areas of primary concern—have limited forecasting compared to major rivers, officials faced the need to make earlier and bolder decisions based on meteorological and rainfall information rather than water levels alone. This created the risk of false alarms, but participants emphasized that prioritizing safety was more important than avoiding potential criticism. At the same time, when river levels temporarily receded, uncertainty arose over whether to continue with staff deployment and response measures. In addition, the need was highlighted for more detailed exercise scenarios that cover not only evacuation actions but also resident support and flood-fighting decision-making under fluctuating conditions. This also reflected lessons from the 2016 disaster, when post-flood confusion and damage posed major challenges for response.

- **Field-level responses:** Early sandbag deployment was identified as particularly important at pumping stations with underground facilities, before heavy rainfall begins. Participants noted that in real disasters staff arrival at shelters may be delayed—making prior coordination with facility managers essential. Training in patrols and road closures was also emphasized, along with coordination with schools and local communities for evacuation support. Communication challenges were noted: while mobile phones were heavily relied upon during the exercise, actual disasters may disrupt networks, requiring improved proficiency in the use of radio communication and the preparation of backup power supplies.
- **HQ management:** Information flow from the headquarters to departments was often relayed through directors, which caused time lags and limited situational awareness among staff, and some departments found it difficult to grasp the broader exercise context. The process of compiling departmental response lists into a single Excel-based record in HQ created duplication and complexity. To address this, the introduction of an online integrated information-sharing system and even video systems was considered necessary. Moreover, orally shared locational information was sometimes misunderstood, underscoring the importance of systematic information mapping and the standardization of damage report formats to support it. Participants also stressed the need to systematically list and map residents requiring evacuation support in advance, and to prepare not only representative contact points but also emergency alternatives for related organizations, while improving methods for confirming residents' safety, particularly for those requiring evacuation assistance. In addition, the possibility of power outages was also raised, pointing to the necessity of printing and storing critical manuals, contact lists, and maps under blackout conditions. Finally, they emphasized that during peak task periods, departmental staff alone would not be sufficient, and cross-departmental coordination and support would be necessary.

5. DISCUSSION

This chapter discusses two main themes based on the results: the experience of decision-making processes and the effectiveness of the simulation scenarios, and the insights, learning, and comparative perspectives gained from the exercises.

5.1 Experience of Decision-Making Processes and Effectiveness of the Simulation Scenario

The results of the exercises highlighted that, beyond simply observing external flood conditions as in Obihiro's past scenario simulations described in the background, the structured scenarios enabled participants to engage in concrete and sequential decision-making. In both municipalities, decision-making was found to follow a series of interrelated processes, resembling and extending the steps identified by Hayashi et al. (2014), such as information

collection, development of the contents of evacuation information, recommendations to the mayor, and issuance of evacuation information. The results suggested that these phases were more detailed and continuous than previously documented, and that some could proceed in parallel rather than in a strictly linear sequence.

Consistent with Seki et al. (2016), decisions on issuing evacuation information—particularly regarding the selection of target areas—were not based solely on hazard maps but also incorporated dynamic meteorological and hydrological information. Similarly, in line with Ushiyama et al. (2003), meteorological and rainfall information was emphasized in the early phases, while river water-level observations played a decisive role at the point of issuing orders. In addition, precautionary actions and internal coordination often began as early as the stage of typhoon formation and the first indications of potential landfall in Japan, demonstrating earlier preparedness than previously recognized. Taken together, these findings suggest that the exercise scenarios, designed with consideration of climate change impacts, provided participants with a comprehensive experience of disaster response across multiple phases, enabling diverse situational assumptions and decision-making processes that closely approximated actual flood conditions. In particular, the results underscored that effective simulation exercises should incorporate large-scale meteorological phenomena, such as typhoon approaches or frontal system developments, to provide context for decision-making. Importantly, unlike many conventional crisis-management exercises (e.g., Katada et al., 2017), these scenarios were developed using climate projections explicitly incorporating climate changes. This not only enhanced participants' perceived validity and trust in the scenarios but also may have helped to mitigate the risk of insufficient preparedness and training for plausible hazard forces—a concern noted in a U.S. Senate Committee report (U.S. Senate Committee on Homeland Security and Governmental Affairs, 2006).

Moreover, this study generated more detailed insights through reflective observation, capturing not only the rationale behind decisions but also participants' hesitation. For instance, it was observed that even under conditions of high uncertainty—such as during nighttime—municipal officials sometimes had to consider issuing evacuation information based primarily on meteorological forecasts. This finding indicates that participants experienced the kinds of difficulties associated with unprecedented situations, as previously suggested by Sato et al. (2011) and Yoshida et al. (2021).

Overall, the exercises indicated that the sequence of decisions broadly corresponded to what has been emphasized in prior crisis management research, but with more detailed documentation of the decision-making rationale. These outcomes were made possible by systematically documenting the decision-making processes and scenarios in chronological order and then conducting reflective reviews with participants.

At the same time, notable differences emerged between the two municipalities. In Obihiro, discussions were centered mainly on decisions directly tied to the issuance of evacuation information, such as opening shelters, and the depth of discussion on decision-making itself was stronger. In contrast, Memuro Town considered not only evacuation information but also

field-level responses and HQ management—reflecting a broader, organization-wide scope of emergency response.

Finally, while Katada (2017) pointed out that in flood-related exercises municipalities often have little capacity to address or discuss the post-flood phase, reflections from Memuro—shaped by the 2016 disaster experience—emphasized that training for this phase is also essential. Participants noted that coping with the multitude of problems and damages emerging during post-flood confusion, and incorporating these reflections as learning to inform prior planning, was just as important as pre-flood decision-making itself. To better simulate such conditions, it may be necessary to extend exercise scenarios to include not only hazard progression but also residents' evacuation behavior and damage situations. This would enable participants to more realistically experience and reflect on post-flood challenges.

5.2 Insights, Learning, and Comparative Perspectives: Obihiro City and Memuro Town

Through post-exercise semi-structured interviews, participants reflected on their decision-making by aligning it with the simulated flood scenarios, which enabled them to identify successful practices, clarify challenges, and generate hypotheses and improvement strategies. This process aligns with Iizuka's (2020) view on the objectives of simulation exercises, showing that the exercises in this study achieved the dual aims of simulation training—experience and learning—through the stages of concrete experience, reflective observation, and abstract conceptualization described in Kolb's model (Kolb, 2014).

Notably, the involvement not only of the risk management unit, which substantively supports the decisions of the mayor as the ultimate decision-maker, but also of the entire municipal staff, strongly influenced the range of insights and learning, highlighting how differences in the scale and composition of participants shaped the outcomes of the exercises. In Obihiro City, because participation was largely limited to the risk management unit—namely the officials directly responsible for issuing evacuation information—the reflections and conceptualizations focused mainly on decision-making itself. By contrast, in Memuro Town, the involvement of the mayor, HQ members, and municipal staff across departments enabled broader reflections that encompassed not only evacuation information but also pre-disaster coordination, HQ operations, flood-fighting activities, information dissemination, and evacuee support, while also revealing interdepartmental issues—such as information sharing between HQ and departments—that are difficult to capture in single-department exercises. These findings suggest that practical operations are most effectively understood through interactions among departments, HQ, field staff, residents, and external agencies. This approach also offers a way to address the information-management challenges identified by Takanashi and Sakamoto (2019) as a major cause of delays in issuing evacuation information. In addition, expanding exercises to include a wider range of stakeholders—including residents and external agencies—would enhance realism and provide valuable experiences and reflections, thereby better preparing municipalities for challenges they would otherwise encounter only in real disasters.

The study remains an important area for further research. Three dimensions merit attention: (1) scale and participants—broader participation yields broader learning; (2) scenario selection—considering prioritization, sequencing, and potential saturation of learning effects, recognizing that it is not feasible to cover the thousands of possible events indicated in climate projections; and (3) evolving social systems—changes such as the 2021 revision of evacuation information levels, advances in forecasting systems, shifts in municipal capacity, and demographic transitions should be incorporated into exercises.

In this light, and consistent with Kolb's model, municipalities should not stop at a single round of training and reflection but engage in iterative cycles of experiential learning. By doing so, they can continuously adapt disaster preparedness to evolving risks, organizational structures, and societal conditions.

Moreover, such continuity can be interpreted as part of the integration between top-down and bottom-up approaches to climate information use, as categorized by Wilby (2022). The top-down approach formulates adaptation based on climate projections and impact assessments, while the bottom-up approach begins with local needs and then seeks relevant climate information. Sustained simulation exercises can bridge these two perspectives by grounding climate projections in locally meaningful decision-making. At the same time, as Rodríguez (2022) emphasizes, trust and transparency in climate information are crucial for its effective use. A key strategy to enhance trust is enabling communities to co-create and directly engage with climate information. In this regard, the simulation exercises and subsequent reflections can be understood as a localized construction of climate information, fostering participation and strengthening the legitimacy of decision-making under climate change. Lastly, as Takeya (2023) argues, non-structural measures should complement structural measures to address residual risk, or serve as interim solutions until structural measures are fully implemented. In this light, the insights gained through simulation exercises—particularly regarding the limits of municipal-level decision-making and emergency response—should also inform discussions on higher-level structural measures, ensuring that lessons from practice are reflected in broader flood risk management strategies.

6. CONCLUSIONS

This study examined the sequential decision-making processes of municipalities during flood disasters and the learning derived from them, through blind-type simulation exercises using climate projections and subsequent semi-structured interviews. Using Kolb's experiential learning model, the analysis focused on concrete experience, reflective observation, and abstract conceptualization, thereby linking practical responses with reflective learning.

The results indicated that municipal decision-making consisted of a series of interrelated processes, shaped by forecasts, river levels, and organizational factors. Key insight was the importance of early preparedness and bold decision-making under uncertainty and depend on the situation and the necessity of monitoring smaller rivers alongside major ones. This result

demonstrates that scenario-based simulation exercises grounded in climate projections could provide experiential learning, and strengthen municipal preparedness and adaptive evacuation decisions under climate change.

Moreover, comparative analysis revealed that Obihiro emphasized decision-focused reflections on evacuation information, whereas Memuro engaged in broader organizational and field-level responses. Expanding the scale and participation of exercises was found to enhance learning beyond evacuation decisions, extending to headquarters management and field operations.

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DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE RESEARCH AND WRITING PROCESS

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