Discover Water

Brief Communication

Fact-finding surveys on role of flood fighting in present-day Japan and future prospects: case studies of Yodo River and Yamato River

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Abstract
Flood mitigation efforts (flood fighting), including raising awareness among local residents, have been crucial in Japan to reduce damage during flood events. In this study, interviews were conducted with three flood fighting management bodies on the Yodo and Yamato Rivers, which still have strong flood fighting corps, and field investigations were performed focusing on the actual operation of flood fighting warehouses, which serve as infrastructure bases for flood fighting. Targets included the flood fighting affairs associations on the left and right banks for the Yodo River and that on the right bank for the Yamato River. The survey results showed that with the progress of flood control measures and river improvement, opportunities to conduct actual flood fighting work during floods decreased in all cases in recent years, but flood fighting techniques and knowledge were passed on through exercises and drills. In addition, the flood fighting warehouses were well managed and maintained their functions as material and equipment storage places and as waiting and meeting places for flood fighting corps members. Considering the intensification of external flood forces due to future extreme weather changes, it was deemed that the role of the flood fighting corps is expected to increase in importance, and it was judged that preparations were being made to respond to this trend. On the other hand, there were some challenges in terms of securing a sufficient number of members due to the shortage resulting from the aging of the corps members and maintaining warehouses from a budgetary standpoint.

Keywords Flood fighting · Flood fighting corps · Flood fighting affairs association · Flood fighting activity · Flood fighting warehouse · Yodo River · Yamato River

1 Introduction

Modern flood control in Japan began with the enactment of the River Act (the former River Act) in 1896, which shifted the focus from low water works to high water works. Combining this law with the Sabo Act (the former Sabo Act) and the Forest Act (the former Forest Act) both enacted in 1897, the so-called Three Laws on Flood Control established a legal foundation. Additionally, river engineering technologies from the Netherlands and several other developed countries were introduced to advance the flood control process progressively. This enabled Japan to avoid the flood damage that used to occur every year in almost all river basins and contributed greatly to building the foundation that supported Japan's rapid economic growth. However, with the nation's modernization, including the population concentration in urban areas and the increase in privately owned vehicles and electrical appliances, the severity of the flood damage became unprecedented when inundation occurred.

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On the other hand, flood fighting has historically been used to mitigate actual flood damage. Miyamura [1] points out that flood control is conducted by planners and administrators, whereas flood fighting is performed by local communities and individuals, and that the two became separated after World War II. Flood fighting in Japan is called *suibo* (*sui* and *bo* directly mean water and prevention, respectively), in contrast to the Japanese word *sabo*, which refers to preventing landslides and debris flows. The complexity of the flood fighting system has changed over time, including the laws and regulations on which it is based, but the core of the system is the Flood Fighting Act (enacted in 1924, most recently revised in 2023).

The purpose of the Flood Fighting Act is to "warn of, protect against, and mitigate the damage caused by floods, rainwater runoff, tsunamis, and storm surges, and thereby maintain public safety". There are 24 articles on flood fighting activities based on this act (42 if each paragraph is included). Examples of main activities include the patrol of rivers and other bodies of water, flood forecasting, the notification and dissemination of water level information, the designation of areas expected to be inundated, evacuation planning, inundation prevention, the issuance of flood fighting warnings, the dispatch of flood fighting corps and fire departments, flood fighting drills, participation in tsunami evacuation drills, and many others.

Flood fighting activities in Japan are carried out by organizing a flood fighting management body, which establishes a flood fighting corps. Flood fighting management bodies are classified into municipalities including special wards, the flood fighting affairs associations that jointly conduct administrative work across multiple municipalities, and the flood prevention associations that rely on the Flood Prevention Association Act (enacted in 1908). As of March 31, 2020, municipalities, flood fighting affairs associations, and flood prevention associations accounted for 98.0%, 1.4%, and 0.6%, respectively [2]. The flood fighting manager is the head of the flood fighting management body. In addition, with the development of flood control, there are fewer and fewer full-time flood fighting corps maintained, and firefighting parties have begun concurrently performing flood fighting duties. As of April 1, 2016, there were 71 full-time flood fighting corps in eight prefectures in Japan, with approximately 14,000 members, while firefighting parties were found in all 47 prefectures, with 2,171 organizations and approximately 850,000 people engaged [3]. Using Niigata Prefecture, located downstream from the Shinano River, the longest river in Japan, as an example, Okuma [4] pointed out the weakening of the flood fighting and analyzed the factors behind it, but the weakening trend is considered to be ongoing and spreading throughout the country.

The transition process of flood fighting organizations, including those that do not mention the weakening of flood fighting, has been well analyzed in historical studies [5–15] focusing on the flood prevention associations of each river, but many of them have already been dissolved or disappeared. On the other hand, some analyses of the flood fighting activities of existing flood fighting organizations can be found. Case studies on the Tone and Ibi Rivers have revealed that the structure of flood fighting activities differs at the individual and community levels [16]. The case of the Arasaki Flood in Gifu Prefecture in 2002 shows that the flood fighting systems of various municipalities differ according to flood damage experience and geographical factors [17] and that people with extensive flood fighting knowledge hold important posts in organizations that respond to floods first [18]. A study of the damage caused by the 2004 flood of the Asuwa River in Fukui found that there were differences in activities in the five target districts due to lack of flood experience, knowledge of the land, and so on [19]. It has also been suggested that subjective norms and flood concerns positively affect communities' willingness to participate in local disaster management plans, including flood fighting corps, in high-risk flood-prone areas [20]. Furthermore, a survey of flood fighting activities in 10 municipalities in Japan reported interesting results that the characteristics of flood fighting activities differ between the midstream areas of local rivers and the downstream areas of urban rivers [21]. However, these are targeted at the actual flood fighting situations in non-metropolitan areas of Japan. As will be discussed in detail later, this paper will focus on the actual flood fighting situation in Osaka City, the second largest city after the capital of Tokyo, by covering the flood fighting affairs associations directly involved in the city.

As mentioned earlier, the frequency of flood inundation in Japan has been drastically reduced due to the progress of modern flood control. In terms of inundated areas throughout Japan, there were eight cases exceeding 200,000 ha from 1961 to 1981, while there were only three cases exceeding 100,000 ha from 1981 to 2017, showing a decrease over time [22]. However, due to the intensification of external weather forces, there has been a series of severe flood damage events on major rivers in recent years. This situation is expected to continue in the future, as Japan is not immune to the effects of global climate change [23], and it is vital to understand the current status of flood fighting to consider how it functions in tandem with flood control. Therefore, this study focused on the Yodo River and the Yamato River, which still have strong flood fighting corps, and ascertained their actual conditions through field surveys.

2 Methodology

Japan's oldest flood diversion channel, called Naniwa-no-horie, was constructed in the lowermost part of the Yodo River (estimated in the fifth century) [24], and Manda-no-tsutsumi, which is considered to be the oldest levee, was also built there. Moreover, the great flood of 1885 was one of the triggers for the enactment of Japan's first River Act in 1896, making it an important river. The Yodo River passes through Osaka City, Japan's second largest city, and flows into the Osaka Bay, and south of that, the Yamato River flows into the Osaka Bay independently. In 1704, the downstream part of the Yamato River was rerouted and became the prototype of the current flow path, but before that, it flowed north and joined the Yodo River. Although it is now independent of the Yodo River, it is still an important river with Osaka City on the right bank downstream (Fig. 1). Both rivers are main streams of the Class A river system managed by the Ministry of Land, Infrastructure, Transport, and Tourism and have a number of important cities, towns, and villages in their basins, in addition to Osaka City. The Yodo River has a main channel length of 75 km, a basin area of 8,240 km^2, and a population of over 10 million within its basin. The Yamato River has a main channel length of 68 km, a basin area of 1,070 km^2, and a population in excess of 2 million within its basin.

From the point of view of natural history, both rivers have major characteristics in their upstream basins. The Yodo River has Lake Biwa, the largest lake in Japan, and the Yamato River has the Nara Basin. In the Nara Basin, there have been many rivers with aboveground beds since ancient times, and the Kamenose landslide, which occurred at the outlet of the basin in one of Japan's leading landslide areas, has caused sediment to move into the Yamato River [25].

The Yodo and Yamato Rivers have several flood fighting management bodies, and there are three flood fighting affairs associations under the mayor of Osaka City as the flood fighting manager organized on the left and right banks of the Yodo River and on the right bank of the Yamato River, respectively, and each has a full-time flood fighting corps. This study conducted interviews and field surveys of these three associations that are strongly related to Osaka in November 2022 to investigate the actual conditions of flood fighting in recent years. The field surveys paid particular attention to the actual management and operation of flood fighting warehouses, which serve as important infrastructure bases for flood fighting activities. The interviews focused on identifying the activities of flood fighting corps during recent flood outbreaks, the operation of flood fighting warehouses in recent years, and the current and future importance and significance of flood fighting warehouses in flood fighting activities as well as uncovering additional peripheral information on the actual state of flood fighting. Based on this survey, the individual situations of each of the three associations were first summarized followed by an analysis of similarities and differences and then a discussion of current issues and the positioning of flood fighting against future flood damage.

3 Yodo River left bank

The Yodo River Left Bank Flood Prevention Association, which was established in 1919 as Japan's first flood prevention association, was later reorganized into the Yodo River Left Bank Flood Fighting Affairs Association in 1958. It has been located in Hirakata City, Osaka Prefecture, from the beginning. Hirakata (see Fig. 1) is important, as it serves as the flood control reference point for the Yodo River. Figure 2 shows the cities and towns under this association's jurisdiction. Table 1 shows a summary of the association as of June 1, 2022, organized from a document provided by the association [26]. This document also included information on the Yodo River Right Bank Flood Fighting Affairs Association and the Yamato River Right Bank Flood Fighting Affairs Association, which was added to Table 1. A flood fighting council is set up in the flood fighting affairs association, but the significance of the flood fighting activities under its jurisdiction can be seen from the fact that the union has its own meeting place (Fig. 3), which is very rare. The flood fighting system is divided into the Yodo River lines, which include tributaries, and the Osaka Bay coastal lines. The coastal lines are the response to storm surges and tsunamis, including the downstream area of rivers. A schematic diagram of the mechanism of the Yodo River lines was prepared from the FY2022 Flood Fighting Plans [27] (Fig. 4).

The main mobilization of flood fighting corps in recent years is represented by the closing of the Yodogawa-ohashi Bridge and Denpo-ohashi Bridge tide gates (land locks) during Typhoon No. 21 on September 4, 2018 in the Yodo River lines and the closing of the iron tide gate of the Shirinashi River in the coastal lines. The Yodo River lines were actually a storm surge response at the time, and except for levee patrols, the actual implementation of flood fighting work on rivers seems to date back to the flooding caused by Typhoon No. 24 in September 1965, at which time 468 people were mobilized. This is due to the progress of flood control measures in the Yodo River system and the fact that there have

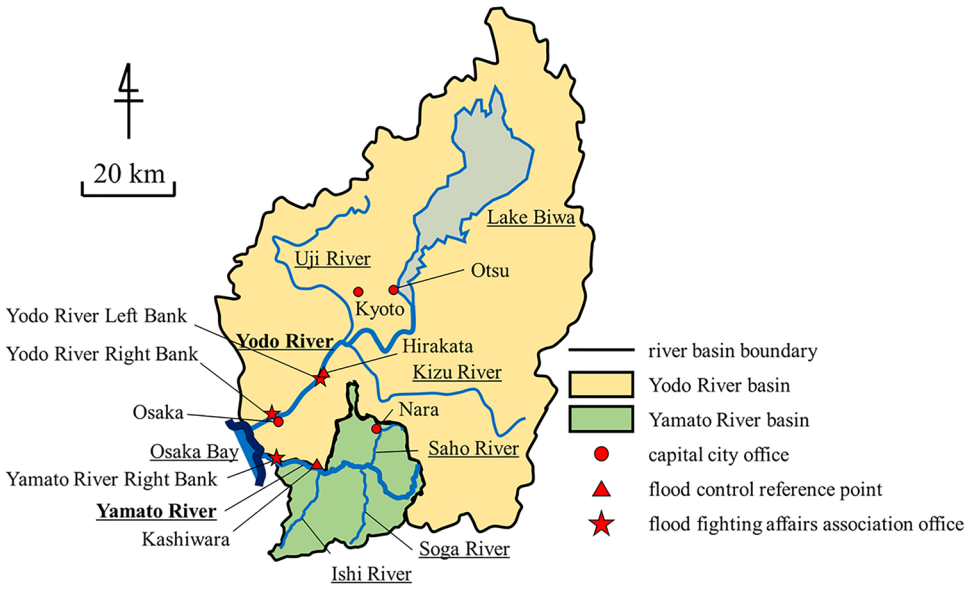

Fig. 1 Basin maps of Yodo River and Yamato River

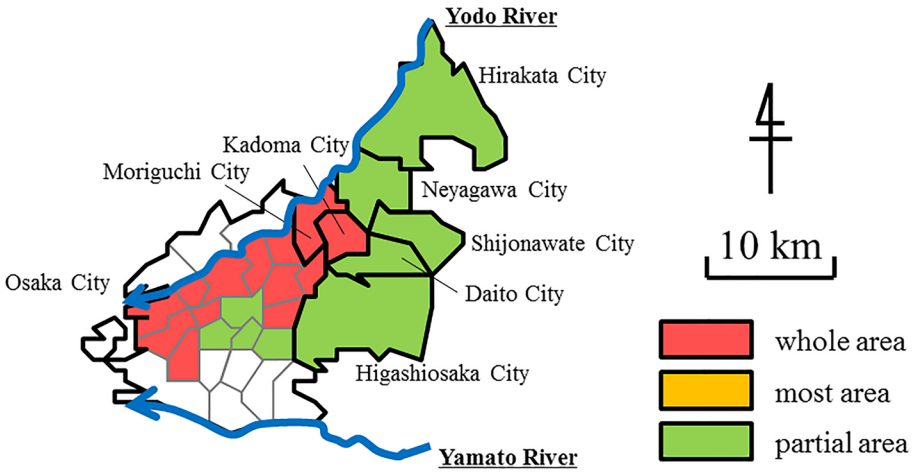

Fig. 2 Jurisdiction of Yodo River Left Bank Flood Fighting Affairs Association

been no extremely large floods that would cause the Yodo River to overflow in the area under its jurisdiction. Since then, the Yodo River lines seem to have been increasingly concerned with storm surges in the low-lying downstream areas of Osaka City. Referring to the FY2022 Flood Fighting Plans [27], a tally of the main dispatch records from September 1953 to August 2021 confirms this trend, with 25 dispatches in the Yodo River lines and 55 dispatches in the coastal lines. As for the Yodo River lines, as mentioned above, responses to storm surges on the river side have also become more common in recent years. As flood fighting activities in response to floods have decreased, the flood fighting methods that were practiced in the past have fallen out of use, and the skills and knowledge have been passed on through flood fighting exercises and drills. Exercises and drills are sometimes conducted jointly with other flood fighting management bodies, but they have had to be scaled back under the COVID-19 situation that has prevailed in recent years.

In carrying out actual flood fighting activities, it is important to secure a place to store materials and equipment and a waiting/meeting place for team members. Flood fighting warehouses meet this need, and as shown in Table 1, this association has 41 buildings for river lines. The warehouses are used to store materials and equipment in accordance with the flood fighting plan, mainly sandbags and piles, as well as various tools. Soil for sandbags is usually procured from designated soil yards. Table 2 categorizes and organizes the detailed data [27–29] on flood fighting materials and equipment that the three associations targeted in this study had in existence in FY2022. Figure 5 shows an example of flood fighting warehouses actually in operation on the left bank of the Yodo River. Flood fighting warehouses also serve as a waiting and meeting place for corps members. Some warehouses are equipped with facilities that allow for a longer stay, and some group leaders maintain them as comfortable spaces. There are also

Table 1 Organization overview of Yodo River Left Bank, Yodo River Right Bank, and Yamato River Right Bank Flood Fighting Affairs Associations (Source: Created from [26])

Flood fighting affairs association	Yodo River left bank	Yodo River right bank	Yamato River right bank
Establishment	11/8/1919	6/21/1926	5/1/1953
Reorganization to current organization	12/1/1958	2/15/1960	12/1/1958
Office location	Hirakata City	Yodogawa Ward, Osaka City	Sumiyoshi Ward, Osaka City
Initial budget for FY2022	Approx. 160 million yen	Approx. 128 million yen	Approx. 102 million yen
Extension of levees to be defended			
River line	41.2655 km	102.674 km	20.2 km
Coastal line*	94.035 km	2.237 km	16.934 km
Total	135.3005 km	104.911 km	37.134 km
Municipality to be defended	Osaka City (15 wards) Hirakata City Neyagawa City Moriguchi City Daito City Kadoma City Shijonawate City Higashiosaka City	Osaka City (3 wards) Shimamoto Town Takatsuki City Ibaraki City Settsu City Suita City Toyonaka City	Osaka City (6 wards) Kashiwara City Fujiidera City Yao City Matsubara City Higashiosaka City
Defensible area	Approx. 190 km^2	Approx. 64 km^2	Approx. 81 km^2
Flood fighting manager	Mayor of Osaka City		
Number of union council members	36	31	21
Number of union staff	9	8	8
Number of members of flood fighting corps (fixed number)			
River line	1926	2283	1031
Coastal line*	3033	618	537
Total	4959	2901	1568
Number of flood fighting zones			
River line	20	28	11
Coastal line*	35	17	7
Total	55	45	18
Flood fighting warehouse			
River line	41	70	19
Coastal line*	35	11	8
Central spare	1	7	4
Total	77	88	31
Tonsyo			
River line	3	3	9
Coastal line*	3	0	4
Total	6	3	13
Radio station			
Base station	1	3	3
Mobile station	75	69	33
Total	76	72	36

(As of June 1, 2022)

*Each coastal line includes the downstream area of rivers

some stations called *tonsyo* for flood fighting activities, but they are now losing their role due to the establishment of flood monitoring systems. Although the *tonsyo* may be completely abolished in the future, the flood fighting warehouses, whether for flood or storm surge response, are supposed to continue to be of great significance. Therefore, when the buildings are renovated, it is said that they will be structurally strengthened.

Fig. 3 Flood fighting council meeting room in office of Yodo River Left Bank Flood Fighting Affairs Association

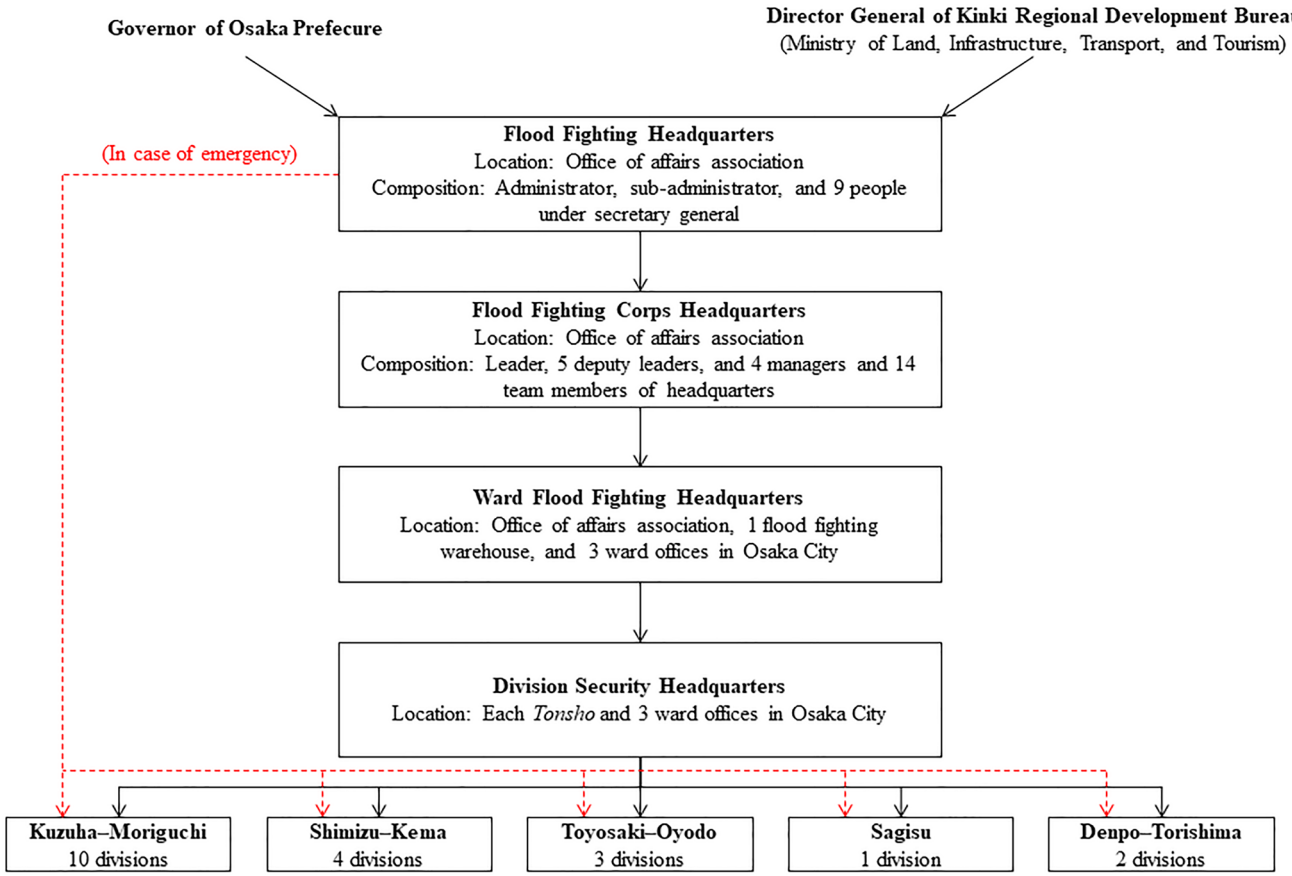

Fig. 4 Outline of flood fighting system of Yodo River Left Bank Flood Fighting Affairs Association (Yodo River lines) (Source: Created from [27])

4 Yodo River right bank

The Yodo River Right Bank Flood Fighting Affairs Association was established in 1960, predated by the Yodo River Right Bank Flood Prevention Association established in 1926. The office is located in Yodogawa Ward, Osaka City, and has jurisdiction over three wards in the city as well as parts or most of five cities and one town in the surrounding area (Fig. 6). The flood fighting corps is responsible for flood and storm surge protection as well as the left bank of

Table 2 Total number of existing flood fighting materials and equipment in FY2022 (Source: Organized from [27–29])

Flood fighting affairs association	Yodo River left bank	Yodo River right bank	Yamato River right bank
Sandbags and water bags	383,851	201,180	128,148
Piles	25,909	65,973	13,134
Ropes	2945	828	1564
Sheets and mats	269	3555	1478
Tools	10,216	15,224	5152
Boats	17	28	10
Miscellaneous items for site work	1819	16,728	3859

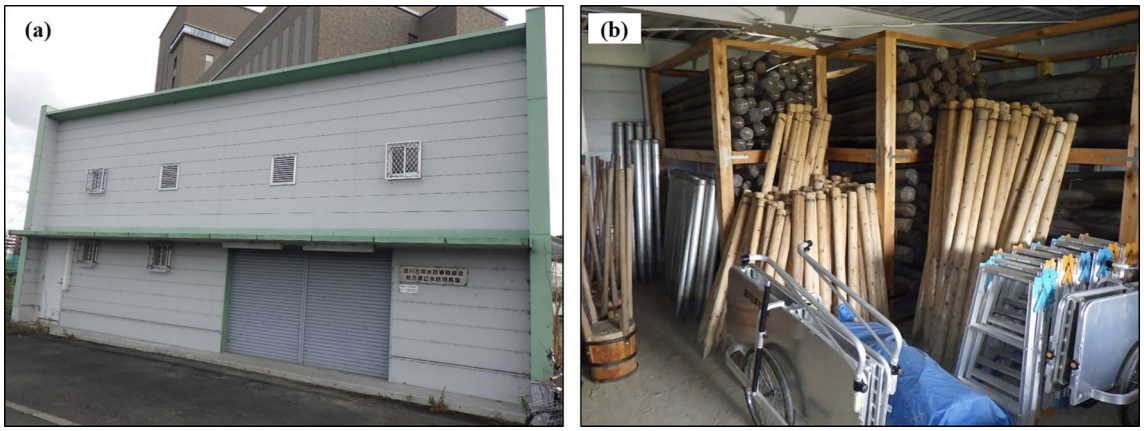

Fig. 5 Example of flood fighting warehouse on left bank of Yodo River. **a** exterior; **b** interior

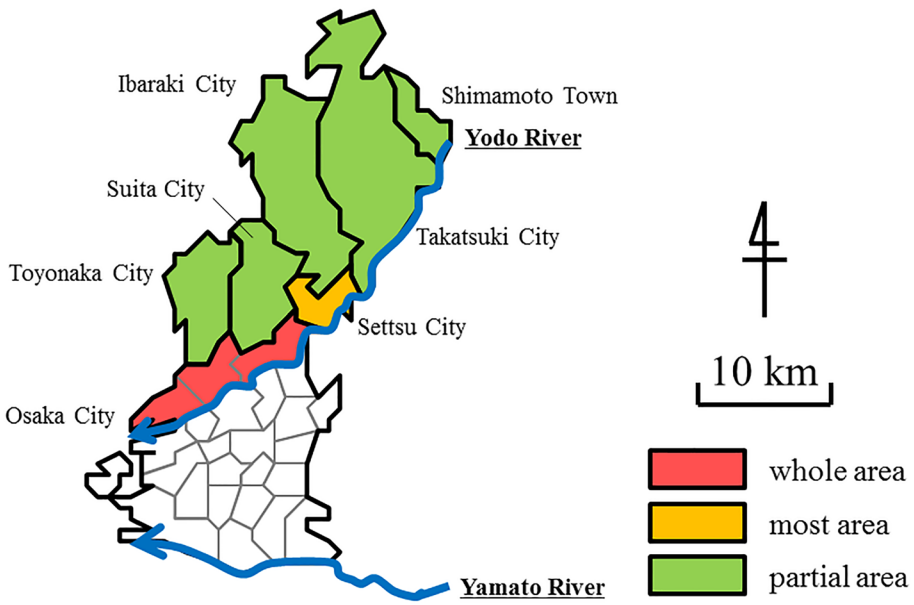

Fig. 6 Jurisdiction of Yodo River Right Bank Flood Fighting Affairs Association

the Yodo River. Although the size of the area of responsibility is about one-third of that of the Yodo River Left Bank Flood Fighting Affairs Association, the number of members and flood fighting warehouses in charge of the Yodo River lines on the right bank side are larger than those on the left bank side, and the initial budget for FY2022 per unit area of the protection area is more than twice that of the left bank side (Table 1). Figure 7 is a schematic diagram

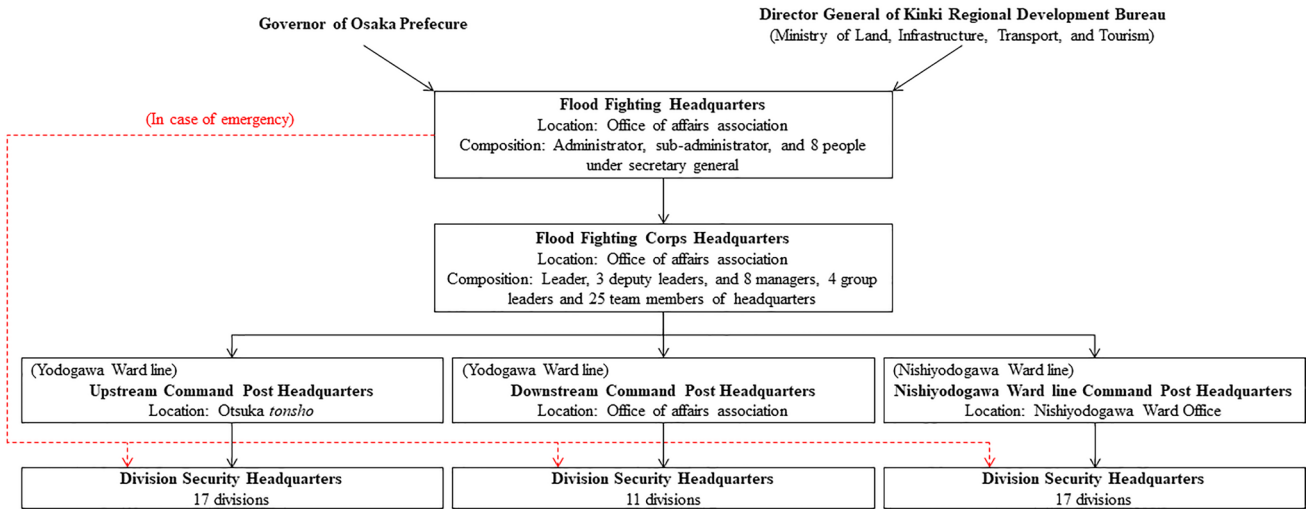

Fig. 7 Outline of flood fighting system of Yodo River Right Bank Flood Fighting Affairs Association (including coastal lines) (Source: Created from [28])

of the flood fighting system prepared from the FY2022 Flood Fighting Plans [28], which is not particularly divided into Yodo River lines and coastal lines, with flood fighting corps near the coast responding to storm surges and other events as appropriate.

The recent activity of the flood fighting corps stands out here as well, as they were mobilized to ensure coastal safety during a typhoon in September 2018, when they responded by closing all the land locks under their jurisdiction. From the FY2022 Flood Fighting Plans [28], the main mobilization records of the flood fighting corps from August 1929 to October 2018 show that they have been mobilized more than 130 times. Before 1964, river flood response dominated, but since then, tidal protection has increased in importance here as well. The 1989 flood in the Akuta River, a tributary of the Yodo River, was the last time flood fighting was actually applied to a river. An exception was the response to leakage from the bank of the Nishijima River, a canal near the Yodo River mouth, during the Great Hanshin-Awaji Earthquake of 1995. The last flood fighting activities on the Yodo River were the same as those on the left bank, when Typhoon No. 24 arrived in September 1965. At this time, in addition to the 901 personnel mobilized from the flood fighting corps, 100 Ground Self-Defense Force members and 75 riot police were in support. As the right bank side has also the same background as the left bank side, there are fewer cases where flood fighting work is actually enforced at the time of flooding. Thus, flood fighting techniques and knowledge are passed on through flood fighting exercises and drills.

There are 70 flood fighting warehouses along the Yodo River (one of which has been converted to a storage place for materials and equipment), and it is said that the *tonsyo* is also being abolished here as well. The policy is to convert one

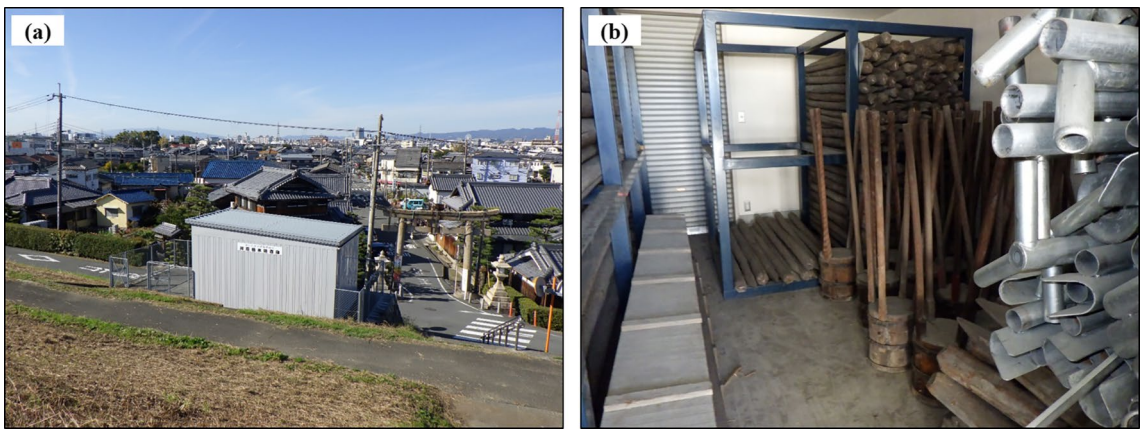

Fig. 8 Example of flood fighting warehouse on right bank of Yodo River. **a** exterior; **b** interior

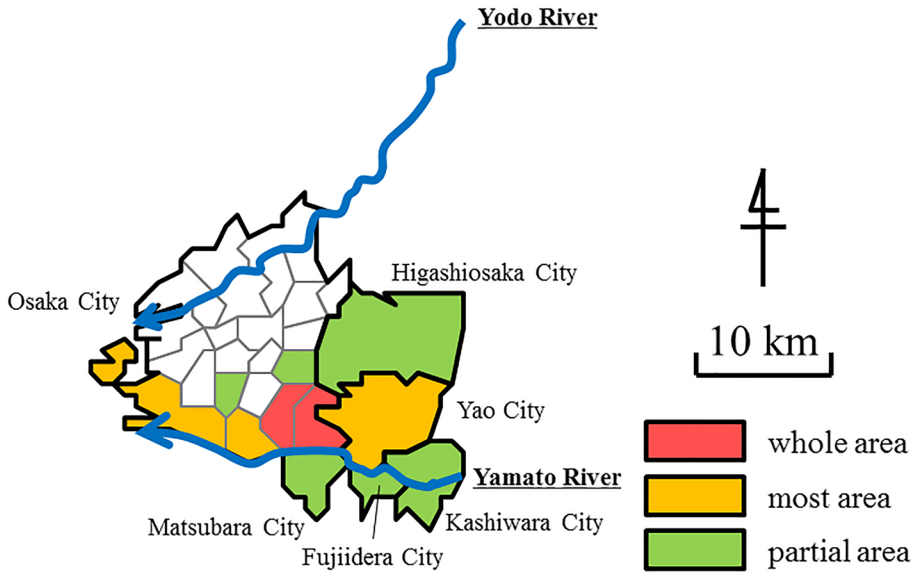

Fig. 9 Jurisdiction of Yamato River Right Bank Flood Fighting Affairs Association

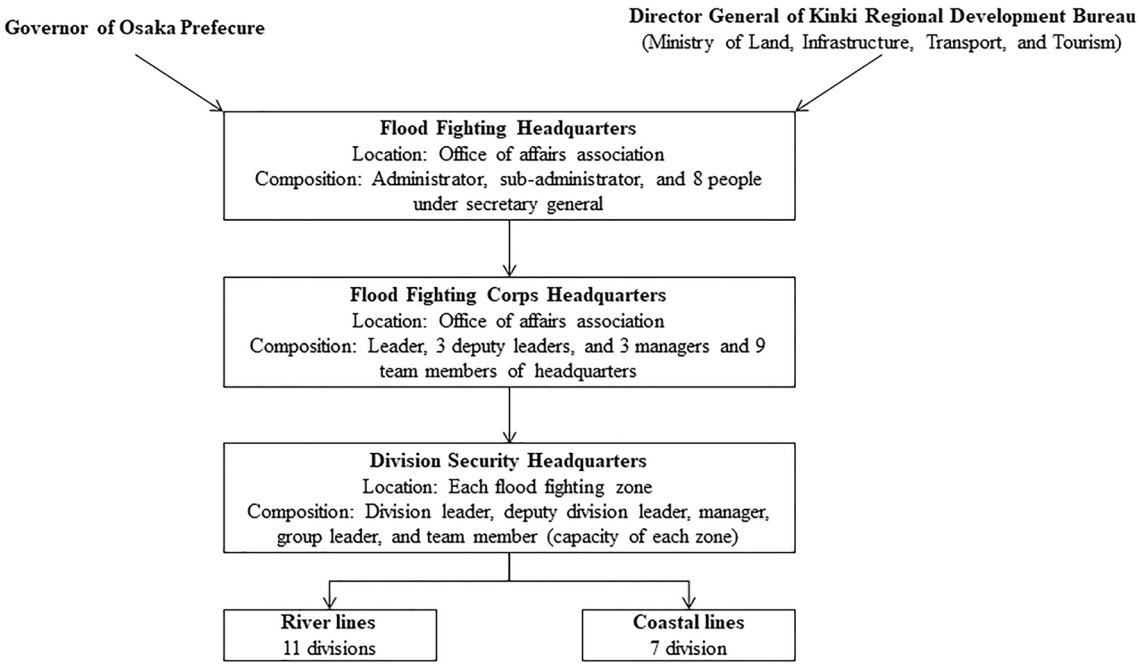

Fig. 10 Outline of flood fighting system of Yamato River Right Bank Flood Fighting Affairs Association (Source: Created from [29])

warehouse per year. Figure 8 shows an example of flood fighting warehouses actually in operation on the right bank of the Yodo River.

5 Yamato River right bank

The Yamato River Right Bank Flood Fighting Affairs Association was established in 1958, predated by the Yamato River Right Bank Flood Prevention Association established in 1953. The office is located in Sumiyoshi Ward, Osaka City, and has jurisdiction over six wards in the city as well as parts or most of five cities in the surrounding area (Fig. 9). The flood fighting system is divided into the Yamato River lines, which include tributaries, and the Osaka Bay coastal lines. The extension of the levees, the number of members of the flood fighting corps, and the number of flood fighting warehouses

indicate that a large proportion of the response is on the Yamato River lines (Table 1). The flood fighting system is not divided into the Yamato River lines and the coastal lines, but each is divided at the end of the same system. Figure 10 is a schematic diagram of the flood fighting system prepared from the FY2022 Flood Fighting Plans [29].

The main cause of mobilization of the flood fighting corps under the jurisdiction of this association in recent years was the huge flood in October 2017, when the highest water level since the establishment of the association was recorded at Kashiwara (see Fig. 1), a flood control reference point on the Yamato River. At that time, a total of 108 people from all the divisions of the flood fighting corps along the Yamato River lines were mobilized, but they simply conducted warning patrols and observed water levels. The last time flood fighting activities were carried out was during Typhoon No. 10 in August 1982, when, in addition to 181 members, 105 people from the Ministry of Construction (now the Ministry of Land, Infrastructure, Transport, and Tourism) came to support the corps. The Kashiwara point is where the Yamato River used to flow north toward the Yodo River. According to the FY2022 Flood Fighting Plans [29], a total of 14 major flood fighting operations were conducted from September 1953 to August 1982 (nine in the Yamato River lines and five in the coastal lines). It is believed that the decrease in opportunities for flood fighting work in recent years may be in step with the promotion of river improvement on the Yamato River. In fact, the peak water level during the October 2017 flood at the Kashiwara site, which was the highest on record, was more than 1 m higher than that of the August 1982 flood. In any case, flood fighting techniques and knowledge are also being passed on through exercises and drills in the Yamato River.

There are 19 flood fighting warehouses along the Yamato River, and although the *tonsyo* is still there, there are no personnel stationed there at present. Figure 11 shows an example of flood fighting warehouses actually in operation on the right bank of the Yamato River. Since the logs stored there also actually serve the function of piles, the main containment items are considered to be the same as those on both bank sides of the Yodo River. This association is increasing the amount of materials and equipment for overflow countermeasures in view of the large-scale flood damages due to the East Japan Typhoon Disaster in 2019. Although the warehouses will remain important in the future, the association is having difficulty in finding funds to replace aging warehouses.

6 Discussion

Since each association was reorganized from the flood prevention association at the time of its establishment to the current association, none of them underwent major organizational changes for more than 60 years up to the present (Table 1), and thus, they can be evaluated as having provided stable activities. However, during this time, the number of flood fighting corps members has been decreasing and they have been aging, and the common problem of difficulty in securing sufficient corps members has been emerging. The number of corps members and their average age in years as of July 2022 for the Yodo River Left Bank, Yodo River Right Bank, and Yamato River Right Bank were 2,447 (fill rate: about 49%) and about 63, 2,196 (fill rate: about 76%) and about 65, and 1,153 (fill rate: about 74%) and about 65, respectively. In addition, the duration of activity was 104, 97, and 70 years, respectively, from the establishment of their predecessor flood prevention associations to the present (Table 1), and although the number of situations in which members

Fig. 11 Example of flood fighting warehouse on right bank of Yamato River. **a** exterior; **b** interior

are mobilized for actual flooding has decreased, as mentioned above, in 2017, for example, the three unions mobilized members for various drills a total of about 50 times.

As noted above, there has been a significant decrease in the inundated areas in Japan over the last 60 years [22], and while there has been remarkable progress in flood control projects, this has been one of the reasons for the weakening of flood fighting activities in the country. Osaka is no exception, and this weakening is also thought to be related to changes in the industrial structure. A quantitative analysis of this relationship will be left to future research, but according to interviews conducted by the author, in the jurisdictions of the three associations surveyed in this study, the increasing number of residents becoming salaried workers is a major factor.

In order to overcome this problem, all of the flood fighting affairs associations are actively recruiting young people regardless of gender and promoting their activities. In recent years, as a result, there have been cases where young people from outside the community have made inquiries after reading flyers. In addition, the associations are actively involved in flood fighting drills and lectures with local residents and schools. In order to secure trucks and other vehicles for transporting materials and equipment that are essential during actual flood fighting activities, all of the associations have established partnerships with private companies for vehicle leasing. In addition, they are building a system for mutual cooperation with other flood fighting management bodies and river administrators. In some recent flood events, the associations have actually responded to requests for the loan of sandbags for flood fighting outside of their jurisdiction. In addition, they have actually responded not only to external water from rivers but also to inland water. In this way, all three associations are prepared to deploy flexible flood fighting activities depending on the situation.

On the other hand, flood fighting warehouses, which serve as the infrastructure base for flood fighting, are used mainly during flood fighting exercises and drills, as the number of occasions for flood fighting work in response to rivers has been decreasing in recent years. Although stored materials are regularly checked and updated, and all warehouses are clean and well maintained, it is important to ensure easy access to materials and equipment in the tense situation of an actual flood outbreak. For this reason, it would be more effective to conduct training during flood fighting exercises and drills by taking out materials and equipment from the warehouses as they are rather than using materials and equipment prepared in advance for the events. In the Netherlands, a country largely exposed to inundation risk, the importance of advance preparation to prevent levee breaches from a logistic standpoint has been emphasized [30]. This perspective aligns closely with the discussions and proposals presented in this paper. In addition, it is difficult for transport vehicles to access some old warehouses. In the event of heavy rains, it may be necessary in the future to operate warehouses in consideration of the accessibility of transport vehicles, since the footholds will be compromised. Recently, flood fighting warehouses have been built alongside disaster prevention stations, which have large parking lots and easy access. While maintaining an appropriate spatial distribution of warehouses, the strategic consolidation of warehouses, including budget issues, will become increasingly important.

Flood fighting activities conducted by humans always involve the possibility of failure, so it is important to conduct a quantitative assessment of the risks involved. A case study in the Netherlands, which incorporated dynamical and stochastic processes [31], and another study in the United States, which applied methods to evaluate the impact of human intervention on the failure probability of flood-protection systems based using risk assessment methods [32], can be instrumental in objectively evaluating the risk of failure in flood fighting activities. Furthermore, a preliminary simulation that quantitatively assesses flood fighting activities to reduce such risks would be beneficial [33]. Recently, there have been initiatives to enhance the software aspects of flood mitigation through web-access tools, which are now being tested in actual municipalities [34]. These approaches are expected to play a major role in improving the accuracy of flood fighting, which, traditionally, has been based on empirical rules. However, irrespective of the approach adopted, comprehensive information on the current status of flood fighting across the entire forecasted flood inundation area is essential as input. While this study focused on Osaka City and its surrounding areas, the methodology employed in this paper will benefit those tasked with gathering and supplying such critical input information.

7 Conclusions

This study surveyed the current status of three flood fighting affairs associations on the Yodo and Yamato Rivers and confirmed that flood fighting still plays a major role in mitigation during actual flood disasters. Although the number of occasions in which they are engaged in actual flood fighting work has been decreasing in recent years due to the progress of flood control measures and river improvement, flood fighting techniques and knowledge are being passed on through exercises and drills. For comparative reference, despite being a different river from the Yodo and Yamato Rivers,

Fig. 12 Example of flood fighting drills conducted on Kiso River in FY2023 (May 28, 2023)

the recent flood fighting drill of the Kiso River is shown (Fig. 12). The Kiso River is notable for having one of Japan's leading flood fighting corps in Japan. In addition, the flood fighting warehouses, which serve as the infrastructure base for flood fighting activities, are being maintained and managed, and it was inferred that they will continue to be significant in the future. On the other hand, there are some challenges in recruiting members for the flood fighting corps and maintaining and updating the aging warehouses.

Concerning flood fighting warehouses, there are three unique flood fighting warehouses in Anpachi Town, Gifu Prefecture, within the Kiso River water system exemplified above. Those exterior walls have been painted by its local artist, attracting the attention of residents and outsiders alike (Fig. 13). Although seemingly unrelated to flood mitigation, these artistic activities are expected to further enhance the presence of flood fighting warehouses, which are important infrastructure for flood fighting, and also raise residents' awareness of flood damage. Besides collaborating with art activities, flood fighting warehouses may also contain retro flood fighting items of high value, and opening the warehouses to the public, to the extent that it does not interfere with flood fighting activities, may naturally help to establish flood fighting awareness among the residents. The author would like to enrich the research from the residents' perspective.

Furthermore, although it was not the main focus of this survey, there are increasing opportunities for flood fighting corps to be deployed in the tide protection lines. Although the impact of rising sea levels due to global warming could not be analyzed, there is concern that tsunamis could strike the Osaka Bay in the future in the wake of the Nankai Trough Megaquake. The reason for mobilization in the past has been storm surges during typhoons, but it is expected that the role of flood fighting corps against tsunamis will become more important in coastal areas. We cannot ignore that this momentum was substantially increased after the devastating tsunami disasters that occurred during the Great East Japan Earthquake on March 11, 2011. While the firefighting units played a significant role in replacing the flood fighting corps and saving numerous lives, it is important to acknowledge that many of their members also sacrificed their lives in the

Fig. 13 Example of flood fighting warehouse located in Anpachi Town within Kiso River water system, with painted exterior walls

line of duty [35]. This situation presents a crucial lesson in balancing the safety of both residents and emergency personnel. The latest Osaka Prefectural Flood Fighting Plan also includes comprehensive information on tsunamis in the Osaka Bay, which affects the estuaries of the Yodo and Yamato Rivers, and features a dedicated section on safety measures for flood fighting workers [36]. Following this study, the author plans to continue the research in other representative rivers and expand it to investigate similar cases in rivers overseas.

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