Original article

Changes in Water network Management since the Meiji Era and Issues Regarding Disaster Prevention at the Foot of Mt. Hira in Shiga Prefecture, Japan

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Abstract : In considering Eco-DRR, it is important to use resources and disaster prevention techniques that make the most of the unique ecosystems of each region. The purpose of this study was to analyze the changes in the water network and its management methods since the Meiji period in Minamikomatsu, Otsu City, located at the foot of Mt. Hira. Based on a literature survey of maps and documents stored in Minamikomatsu, interviews, and field surveys, a water network map was created for each period, and the changes in the management of the water network and issues related to disaster prevention were analyzed. As a result, we were able to confirm the traditional wisdom and techniques of water use and drainage by controlling water intake. On the other hand, the system of water network management has changed with the development of government, agriculture, tourism, and residential areas, and integrated management has become difficult. In addition, changes in the shape and flow of waterways and their disappearance have impeded and fragmented the flow in downstream areas, creating problems for disaster prevention. In the future, it will be important to secure and regenerate the continuity of water networks for watershed basin water control, and to establish a comprehensive water network management system.

Key Words : water network management, river basin management, local community

INTRODUCTION

In 2021, the Ministry of Land, Infrastructure and Transport started the "Basin Water Control initiative" for the entire basin for all parties including administration, companies, residents, etc., in addition to the water control managed by river and wastewater managers. There is an increasing need for comprehensive flood control measures, including river basin measures (Isaka, 2010). Advances in such flood control measures need to be made in the future based on the examination of measures throughout all river basins ("Effective flood control including measures in basins", River Council of Japan, 2000). Advancing "basin-based flood control" requires strengthening the water retention, infiltration, and storage capacity of the entire basin, and restoring the water cycle system itself (Shimatani, 2010). There is also a need for traditional river management technologies that are in line with the local culture. Characteristics of traditional river management include technologies that (1) utilize the natural flow of the river; (2) minimize damage to the basin; (3) match the characteristics of the region and river; and (4) incorporate maintenance and management into daily life ("How should traditional technologies be used for river management?", River Council of Japan, 2000). Takahashi (2008) stated that technologies are a means to an end, and emphasis should be given to the climate and history of river basins based on the way that people have lived with rivers.

Populations in local communities face an ongoing decline, and river disaster prevention facilities constructed during the high economic growth period of Japan from the 1950s to the 1970s continue to age; amidst these factors, ecosystem-based disaster risk reduction (Eco-DRR) is one of the means for

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addressing the large-scale disasters accompanying climate change (Ministry of the Environment, 2016). Innovative measures were implemented in the past when disaster prevention methods such as sediment control facilities were not common; these measures minimized damage by effectively using the local natural environment in order to control natural disasters such as floods and landslides. Important factors when considering Eco-DRR include not only physical characteristics of the water network such as the lakes and waterways connected to the rivers, but also "traditional and local knowledge", which are the techniques for resource utilization and disaster prevention that can be applied to the unique ecosystems of each region. There is a need for innovations that reduce damage, such as applying the concepts of Eco-DRR to waterway maintenance or management, or combining with conventional gray infrastructure to ward off disasters that exceed the project scale.

The importance of focusing on the water network has been indicated when clarifying local landscape characteristics (Ohbi, 2004). The related previous study has clarified water use patterns and landscape formations in each settlement from the morphological characteristics of flow channel networks caused by topographical features (Miyoshi et al., 2007). There are also examples that have analyzed the relationships between the spatial structures of settlements and water networks within settlements, functions of water networks in daily life (Yamazaki, 2010), and the relationships between water use in settlements and residential areas (Tenma et al., 2013). Furthermore, there are studies in which historical documents have been used to reconstruct historical waterway networks and utilization patterns to analyze changes in flow channels and their causes (Sawa et al., 2011; 2013). Other researchers have analyzed resident awareness of water networks and associated landscape characteristics based on the water network structure of the river basin (Ohbi, 2008). There is an increase in the body of research on the characteristics and functions of water networks, which are a landscape element, as an important finding in advancing river basin water control and Eco-DRR initiatives. However, there are few studies or discussions from the perspective of disaster prevention and mitigation in local communities which are rooted in local nature or culture.

Near the base of Mt. Hira there are a series of steep mountains with summits over 1000 meters, and rivers of various sizes flowing down through the alluvial fan into Lake Biwa, which extends to the east. Settlements at the foot of Mt. Hira are home to many historical materials such as documents and drawings from the Edo period (1603–1867) onward, which contain information on natural disasters such as floods and debris flows as well as disaster measures and water network management. In "Traditional and Local Knowledge of Eco-DRR at the foot of Hira Mountains" (Research Institute for Humanity and Nature Eco-DRR Project, 2020), there are specific examples of local knowledge and technologies for facing natural blessings and disasters since the Edo period (1603-1868). These materials can be used to thoroughly grasp and analyze the landscape characteristics, traditional river management technologies, and their changes.

In this study, it clarifies the changes in the water network at the foot of Mt. Hira in Shiga Prefecture and its management from the Meiji era to the present day. Study objective is to examine the characteristics of water network use in a local community and countermeasures and issues related to disaster prevention and mitigation, toward a new way of water network management directed toward "basin-based flood control" initiatives.

The Japanese Calendar was used throughout this paper, which corresponds to the Meiji (1868-1912), Taisho (1912-1926), and Showa periods (1926-1989).

1. METHODS

1.1 Overview of Study Area

Minamikomatsu in Otsu city, which is located in the foot of Mt. Hira was selected as the study site.

Figure 1 shows the positions of the three rivers (Odo, Yanomune, and Sunaji rivers) that constitute the water network to be analyzed, as well as the surrounding topography and facilities. Prefectural

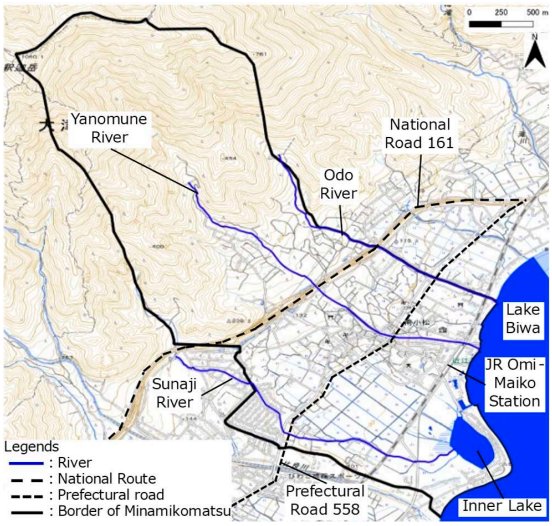

Figure 1 Outline of the survey area and water networks

Road 558 runs through the center of the village, Shiga Bypass (National Route 161) runs along the mountains, and the JR Kosei Line runs along the lake shoreline. The Odo River flows through the forests and farmlands on the border of neighboring Kitakomatsu, and the Yanomune River becomes a raised bed river and flows through both historical settlements as well as new residential areas near the lake shoreline; both flow into Lake Biwa. The Sunaji River flows through new residential areas and farmland along the mountains and into the inner lake. The water network of Minamikomatsu is mainly composed of rivers, reservoirs, the inner lake, and Lake Biwa. The villages have access to abundant spring water, and there is a spring area at the end of the alluvial fan. Streams from the mountains also flow into the inner lake located in Omimaiko on the Lake Biwa shoreline, and a rich ecosystem is formed from the wetlands which include reed communities and rare species such as *Euphorbia adenochlora*. Figure 2 is a postcard of the inner lake during the early Showa era (around 1920-1945), which shows a simple pier in an open section of the reed belt on the inner lake shoreline. The Lake Biwa shoreline and area around the inner lake, with its white sand and green pines, were designated along with Mt. Hira as the Lake Biwa Quasi-National Park in 1950.

Figure 2 State of the inner lake from the early Showa era (Private Collection)

The population of Minamikomatsu was 765 in 185 households in 1881, but this has changed in the last 10 years to 1,830 in around 780 households, and as of 1 April 2020, the population was 1,813 in 800 households.

Research has been done on land use and disaster response in Minamikomatsu from the Edo period to the early Meiji era (Ando et al., 2020) as well as on the use of protection forests and vegetation (Ando and Fukamachi, 2020); this work showed that embankments and waterways made of local stone have been constructed at key points in response to debris flows and floods, with vulnerable land along rivers becoming "wasteland" and functioning as protection forests consisting of mainly Japanese red pine. Furthermore, no major changes in land use patterns occurred at the foot of Mt. Hira from 1893–1932, and traditional land use patterns were maintained from the early modern era. However, parts of the forest subsequently changed to residential areas, and the opening of the JR Kosei Line in 1974 resulted in further development of the residential area. The land converted to residential areas between 1975 and 2016 was 60% forest, 27% paddy fields, 8% fields, and 5% wastelands.

1.2 Changes in the water network and its management since the Meiji era

In order to determine the social context that affected the water network in Minamikomatsu from the Meiji era to the present day, a literature review was conducted. Local historical materials (Shiga Prefecture, 1979; Shiga Town History Editorial

Committee, 1996; 1999; 2002) and administrative materials relating to Minamikomatsu (Shiga Prefecture, 2019; Torigoe and Kada, 1984) were used to summarize the events relating to land development and disaster prevention.

A village drawing map of "Minamikomatsu Village, 16 district, Shiga County, Omi Province in 1874", a cadastral map of "Minamikomatsu Village, Shiga County in early Meiji era", and survey maps of the inner lake created in Minamikomatsu were analyzed to clarify the water network and its management during the early Meiji era. The village drawing maps were used to determine topographical features of the water network and disaster prevention facilities; Notes were written in various places on the old maps, providing information regarding the existence and characteristics of river embankments. The cadastral maps and survey maps of the inner lake were used to determine the flows of the rivers and waterways at the time as well as the state of the inner lake. The old record "Investigation Document in 1873 for Various Expenses of Minamikomatsu Village" was used to obtain information on water network management, such as projects and expenses relating to disaster response.

First, the interpretation of the topographic maps and residential maps of the latter Meiji era (Japanese Imperial Land Survey 1:20,000 Topographic Map "Komatsu Village", 1893; Geospatial Information Authority of Japan 1:25,000 Topographic Map "Mt. Hira", 1932, 1971, 1986, 1996; Zenrin Co., Ltd. Residential Map "Otsu City", 2018) was conducted. Then, the water network map for 1971 and 2018 were prepared by using the geographic information system software QGIS 3.4.

A water network map was created for the water network of each period and the associated land use was overlaid onto the top of the Geospatial Information Authority 1:25,000 Topographic Map "Mt. Hira" in 1971 and Zenrin Co., Ltd. Residential Map "Otsu City" in 2018. Land use was shown by creating polygons for rivers, waterways, roads, regional boundaries such as lines, and others.

Furthermore, water networks that were not specified in the previously-mentioned topographic maps and residential maps were supplemented using the "Agricultural Promotion Area Map (No. 7), 1980" and the Minamikomatsu Water network Management Map. The Agricultural Promotion Area Map shows the paddy field plots, which use the rivers and waterways from the mountains as well as those which use water extraction pumps when conducting agricultural field improvement; these maps can be used to interpret the paddy field plots and waterway flows prior to agricultural field improvement. The Minamikomatsu Water Network Management Map is a map of the flow of rivers and waterways in 2018 as shown by the local land improvement district manager at the time of interview surveys (Land improvement district: A legal entity established under the Land Improvement Law for the purpose of implementing land improvement projects based on said law). The Water Network Management Map shows the flows of rivers and waterways as well as the open surface of the inner lake. The map symbols in the previously-mentioned topographic map were also used as a reference to show the land use distribution at the time.

From April 2019 to January 2021, we conducted interview surveys with local residents regarding water network management since the Taisho era (1912–1926). There were five interviewees in total: including leaders of the Minamikomatsu residents' association, land improvement district, and common land management association, which are organizations of local communities associated with the water network. The manager of the water use facilities for water intake, as well as those with experience managing the facilities were interviewed as well. The interview content included the characteristics of water networks as well as management entities, methods, and issues. Field surveys on water diversion channels (facilities created across embankments to take water from rivers), waterways, ponds and water extraction pumps which were installed on rivers, were conducted to confirm the distribution and mechanics of water use facilities.

2. Results and Discussion

2.1 Disaster history and development projects in the Minamikomatsu water network since the Meiji era

Disasters in Minamikomatsu included river and lake flooding up until the 1950's, but these have decreased in frequency since the completion of the Nango Weir in 1905 and the start of sediment control projects in the Yanomune River in 1954 and Odo River in 1964. Meanwhile, there has been an increase of forest damage on the lake shoreline and sand loss due to typhoons (Kada,1984; Shiga Town History Editorial Committee, 1996).

Development projects relating to the waterways included water extraction pump installation (1959) and agricultural field improvement (1981–1986). Infrastructure projects related to traffic included the opening of the Kojaku Railway (1931), opening of the JR Kosei Line (1974), and the start of operation of the Lake Biwa West Transit Road and Shiga Bypass (National Route 161) (2001) (Shiga Town History Editorial Committee, 1999; 2002).

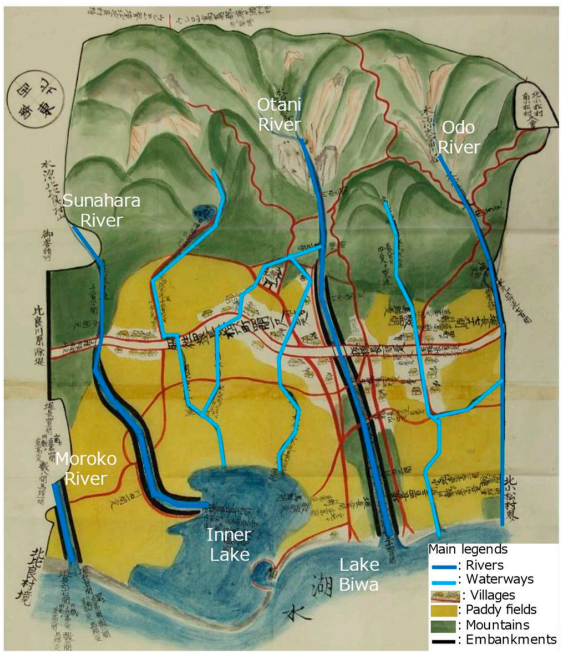

Figure 3 A village drawing map of "Minamikomatsu Village, 16 district, Shiga County, Omi Province in 1874" (Shiga Prefectural Archives Collection, Partially processed)

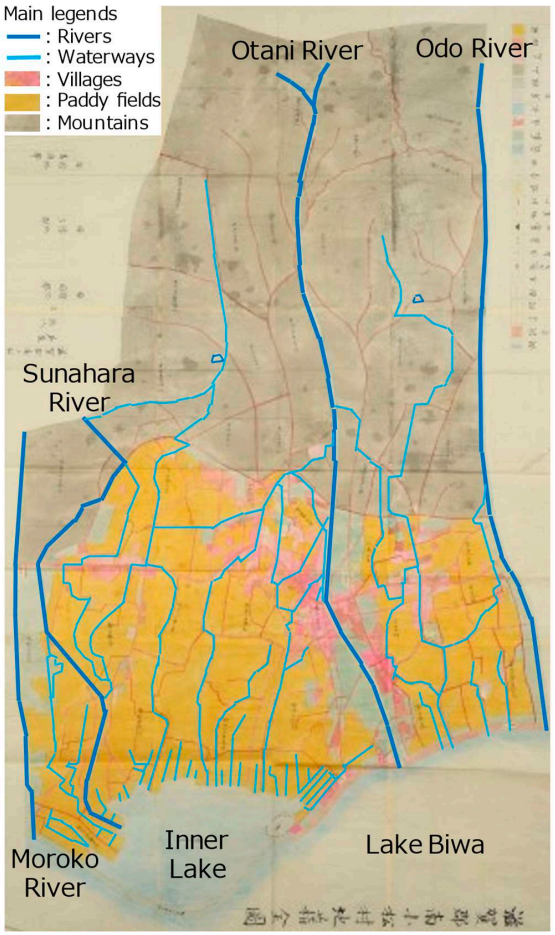

Figure 4 Cadastral map of "Minamikomatsu Village, Shiga County in early Meiji era" (Minamikomatsu Collection, Partially processed)

After the latter half of the Meiji era, there was a movement to develop the area around the lakeshore as a tourist destination under the name of "Omi Maiko". When the Omi Maiko Hoshokai (preserving beautiful sceneries association) was established in 1935, tourism development in collaboration with local governments and companies gradually progressed (Narita and Ochiai, 2020). In 1950, Lake Biwa Quasi-National Park was established, followed by the creation of the collective facility area. The Hira Mountains and the shores of the lake in Minamikomatsu were designated as a part of this, and further tourism development was carried out. Omimaiko was designated as a facility complex within the Quasi-National Park in 1962, and

tourism development projects were implemented by common land management associations and companies on the lake shore and around the inner lake (Shiga Town History Editorial Committee, 2002).

2.2 Water network in Minamikomatsu

1) Water network in early Meiji era

A village drawing map of "Minamikomatsu Village, 16 district, Shiga County, Omi Province in 1874" is shown in Fig. 3. The historical drawing map shows that four rivers flowed from the north in the Meiji era: Odo River, Otani River (currently Yanomune River), Sunaji River (currently Sunaji River), and the Moroko River. Based on the interview, the Moroko River was a tributary referred to as an "abandoned river" that was used for reducing damage by flowing water, sand, and gravel when the Hira River flooded. There are descriptions of embankments constructed on both sides of each river, which indicate preparations against flooding and sediment-related disasters. Several notes found within the historical drawing map describe the riverbed being higher than the residential areas and paddy fields, indicating that it was a raised bed river. The map also shows how weirs and water diversion channels were used upstream of the river and at reservoirs to draw water into irrigation channels. A cadastral map of "Minamikomatsu Village, Shiga County in the early Meiji era" is shown in Fig. 4. The waterways were sourced from mountains, rivers, and springs; waterways that utilized the slope of these mountains extended throughout the village and the paddy fields. In addition, there were abundant springs around the inner lake which fed water directly into the inner lake. The inner lake had an area of approximately 21 ha according to the survey map of the inner lake (Meiji era) stored in Minamikomatsu; the surrounding area was described in the map as being used for paddy fields. The local community managed the lake shoreline, inner lake, rivers, and waterways as a single water network.

Part of the "Investigation Document in 1873 for Various Expenses of Minamikomatsu Village" is shown in Fig. 5. The document shows that residents' associations in Minamikomatsu managed the water network; it also shows the expenses and workers involved in the restoration work when the river flooded,as well as the repair and dredging work of waterways that were damaged during floods and debris flows. The document also shows that the amount of water taken from water diversion channels was controlled by a Isekimori, who was a manager that received requests or selected from the local community.

2) Water network in 1971

A water network map of Minamikomatsu in 1971

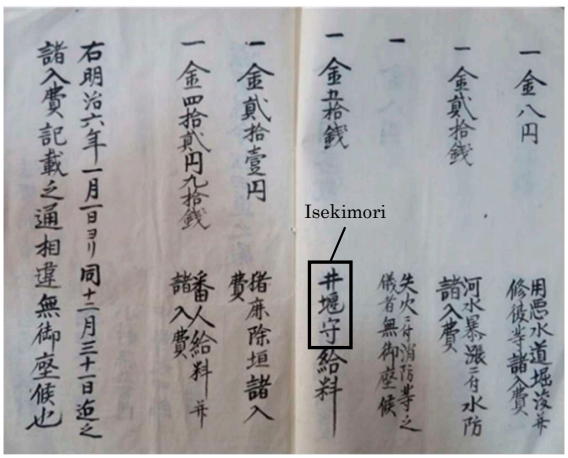

Figure 5 Part of the "Investigation Document in 1873 for Various Expenses of Minamikomatsu Village" (Minamikomatsu Collection)

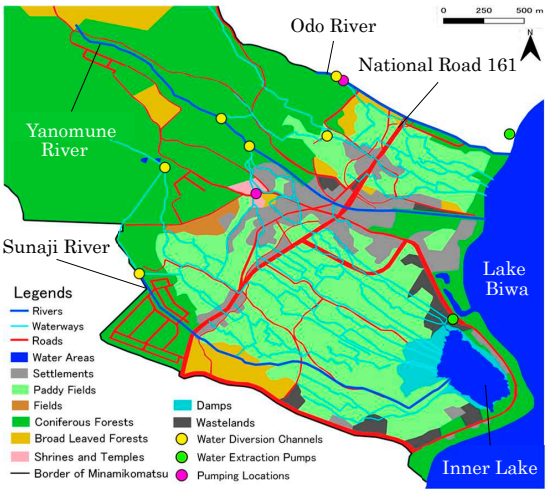

Figure 6 Water network map of Minamikomatsu in 1971

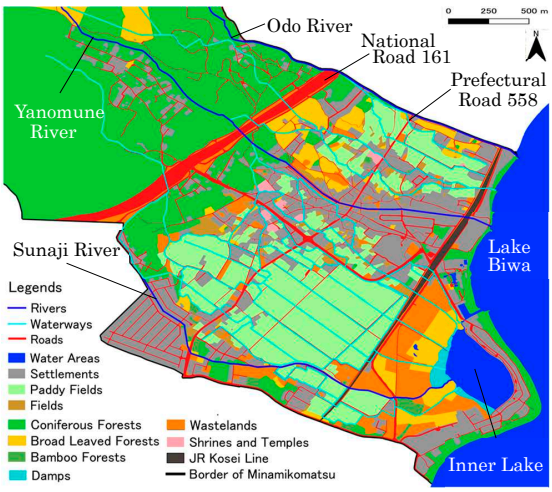

Figure 7 Water network map of Minamikomatsu in 2018

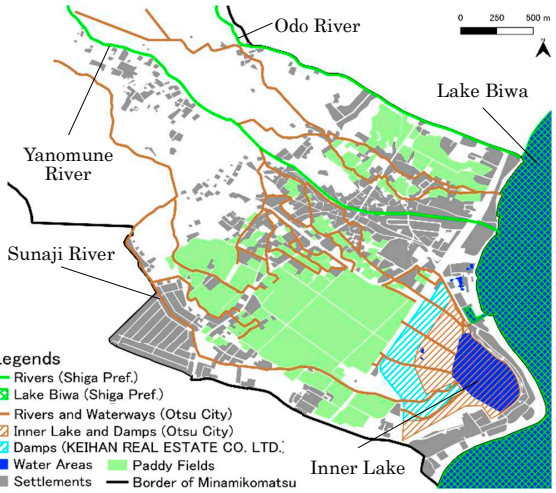

Figure 8 Locations of the water networks managed by the goverments and companies in 2018

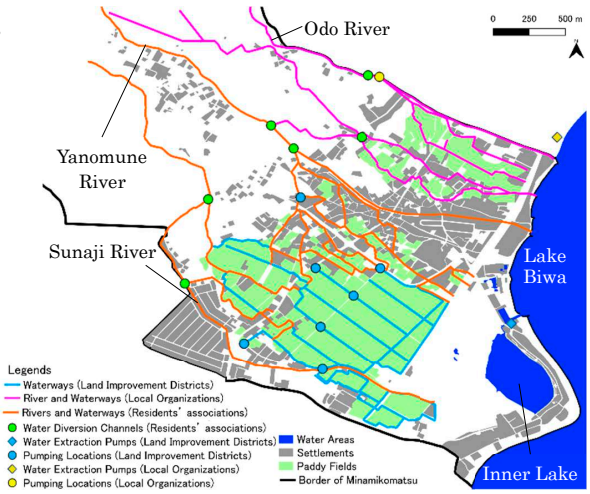

Figure 9 Locations of the water networks managed by local organizations in 2018

is shown in Fig. 6. According to the interview survey, dams and concrete-lined flow channels were constructed on the Yanomune River and Odo River as a result of sediment control projects, which fixed the flow channels and transformed the Moroko River into a road. According to the interview survey, following the amendment of the River Act, the government began to take charge of river maintenance and large-scale disaster recovery projects; the local community shifted to weeding and cleaning the river and lake shoreline as well as controlling the water diversion channels and dredging the waterways for disaster prevention and mitigation. As the springs around the lake shoreline dried up because of the sediment control projects on the Yanomune River, a pump was installed to supplement the shortfall, and water from Lake Biwa was used as irrigation water for paddy fields during periods of insufficient rainfall.

Along the water network which connects the mountains to the lake, artificial water control channel that did not match the surrounding landscape or topography was revealed, which would eventually prove to be a burden due to its maintenance costs.

3) Water network of Minamikomatsu in 2018

A water network map of Minamikomatsu around 2018 is shown in Fig. 7. The small-scale waterways were integrated and converted into linear flow channels as a result of agricultural field improvement and the opening of the JR Kosei Line. The connections from the mountains to the lake became increasingly interrupted through the influence of the construction of roads and railroad tracks. There was a large decrease in the number of waterways that connected the area around the inner lake and Lake Biwa, including small-scale waterways associated with residential areas and paddy fields, which disappeared. According to the interview survey, the land improvement district took on the responsibility for agricultural water

management as a result of agricultural field improvements and installed water extraction pumps, a number of which are found scattered throughout the area. New waterways were constructed on the slopes along the JR Kosei Line and Shiga Bypass routes. The area of paddy fields decreased as a result of development and the abandonment of cultivation, and the number of waterways on the lake shoreline and around the inner lake also decreased. Land use for housing and waste land expanded in areas that had been forests or paddy fields in 1971 (Fig. 6) while the area of wetland and paddies decreased near the inner lake. A facility complex was installed in the Quasi-National Park, which led to increasing tourism, and in turn, the construction of accommodation facilities and parking lots on the lake shorelines with its white sand and green pines and on the reed belt along the east shore (Shiga Town History Editorial Committee, 2002).

The locations of the water networks managed by the governments and companies are shown in Fig. 8 and those managed by local organizations are shown in Fig. 9. According to the interview survey, Otsu city and Shiga Prefecture manage most of the waterways; however local organizations manage the water networks in the mountains, residential areas, and paddy fields. In water networks such as rivers, where the scope of management by the government and local organizations overlap, the division of labor is made so that the government is responsible for management involving large-scale construction such as disaster recovery, and local organizations are responsible for management necessary for daily life, such as cleaning. After the 1980's local organizations such as land improvement districts and common land management associations were created separately from existing residents' associations for specialized agricultural and property management purposes. This changed the residents' association-centered system in which the entire water network was managed by the local community as a whole. Companies began to take charge of the maintenance and management of waterways in new tourism facilities and residential areas, thereby increasing the number of waterways in which local communities were not directly involved. Due to the fact that companies and many new residents were not affiliated with local organizations such as residents' associations; there was an increase in the number of residents and facilities that were not directly involved in water network management.

2.3 Issues relating to disaster prevention in present-day Minamikomatsu

According to the interview survey, changes in the water network due to agricultural field improvement and the development of the Shiga Bypass and residential areas caused sediment to accumulate in the waterways. This sediment blocked the small-scale waterways used during the Meiji era until the 1980s; from the time when the water network changed to the present, this blockage caused flooding (although small in scale) in the waterways during rainfall events. The flooding of waterways has led to damage in people's daily lives because the paddy fields extended into areas that underwent agricultural field improvement, and newly developed settlements spread downstream of the Shiga Bypass. Paddy fields that were no longer in use were developed into settlements in the areas between the Odo River and Yanomune River as well as the lake shore from the Prefectural Road; however, interview surveys showed that this development reclaimed the waterways not under the management of Otsu city in the same manner as the paddy fields, effectively disconnecting flows from upstream. These waterways are located in lower elevations than those managed by Otsu city, and these issues cannot be sufficiently addressed by the replacement ditches newly installed in the settlement. These result in water overflowing at the point where the waterway flow is interrupted during rainfall events leading to flood damage in the settlements. In these ways, the water network that was changed as a result of development has new disaster risks that were not seen in the Meiji era.

According to the interview survey, management of the waterways that were replaced as a result of agricultural field improvement was shared by the

government, which controls the dredging of sediment accumulated during heavy rainfall, and the local organizations, which conduct routine cleaning. At the local level in particular, residents' associations and land improvement districts conducted local cleaning called "Kawabushin" (river work by participation) every April in order to remove sediment in rivers and waterways. Meanwhile, residents' associations might respond to the flooding caused by the interruption of waterways in settlements upon being contacted by the new residents living there; however, progress on recovery is difficult because the waterways are privately owned and not managed by the local government, thus their management is beyond the scope of local organizations.

CONCLUSIONS

The water network of Minamikomatsu has greatly changed due to erosion and sediment control projects, agricultural field improvement, opening of the Shiga Bypass, and development of residential areas; such changes are closely related to the reduction of disaster risk as well as agricultural and traffic development. These changes have included the construction of waterways which cut across the mountainsides as well as those which flow into Lake Biwa; and the expansion of residential areas, tourist facilities, and "wasteland". The previously existing rivers and other waterways were replaced, eliminated, and fragmented due to the development of roads and residential areas, impeding the water and sediment intake functioning of the inner lake and Lake Biwa. Recently, there has been an increase of issues including rapid changes in river ecosystems and floods caused by sedimentation.

We were able to confirm the use of traditional knowledge such as the wisdom and techniques involved in water intake control, water use, and water drainage as a form of water network management by local communities. However, administrative and local residents' waterway management methods did not work in an integrated manner. In addition, artificial water networks such as water extraction pumps have increased maintenance costs and placed a heavy burden on the local community. In the future, comprehensive water network management initiatives will be important along with ensuring and regenerating the continuity of water networks toward the realization of basin-based flood control. Further discussions are needed on how various parties such as companies and new residents can act as members of a local community to enjoy the benefits of the water network and share roles among themselves for disaster prevention and mitigation.

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