Restoration projects and mitigation of post-flood hazards – a case study on the Maruyama River in Japan

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Abstract

The hazardousness of potential flooding and environmental deterioration face river basins throughout the world. Rivers in Japan are relatively short in length and steep in elevation along the banks, which are supposed to funnel rainwater and create floods due to heavy rain from typhoons/hurricanes. In addition, the clearing of forested areas due to widespread residential development in Japan and a lack of forestry workers have led to a broad decline in the riparian forest ecosystems. The study examined the recovery of the Maruyama River basin following the flood disaster in 2004. The Maruyama River disaster-relief and restoration projects addressed the mitigation of environmental damage as well as economic impacts. The Maruyama River basin is a noted habitat of the Oriental white stork, which became extinct in 1971, and was reintroduced as the basin through the breeding program in 2003. The 2004 flood destroyed the stork habitat. As a part of the recovery effort, the Japanese government has worked with the Toyooka City government and the Maruyama River Basin Committee to rebuild and expand the habitat of the stork. Preserving the habitat of another endangered species, the committee has added the Japanese giant salamander into a species name list in the restoration plan. These projects are expected to reinvigorate the local economy and preserve the environment of the river basin.

Keywords: restoration, rehabilitation, flood hazard, stork, salamander, habitat.

WIT Transactions on Ecology and the Environment, Vol 118, © 2008 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/FRIAR080191

1 Introduction

Although flood prediction has improved in recent years, we cannot yet predict flood events as readily as earthquake occurrence. Natural catastrophes have increased alarmingly in recent decades and the costs associated with these events from 1996 to 2005 were almost seven times higher than in the 1960s. An analysis of the one hundred most deadly and expensive natural catastrophes since 1950 revealed that flooding caused more than half of all fatalities [1]. While working on improvements to flood prediction, governments have recently started to focus on enhancing flood preparation measures to reduce the potential impacts in stricken areas and assist potential flood victims. In addition, recent interest in the restoration of rivers has focused on mitigating damage to important riparian habitats. For example, rehabilitation measures now combine flood control planning with river restoration efforts after flooding, recognizing the importance of river ecosystems to flood abatement. Environmental restoration of urban rivers has included the conservation and renewal of wetlands, expansion of river width, and the modification of groins by removing low levees, the elimination of debris barriers to restore the river shoreline, the reduction of water pollution, the restoration of former river configurations, and the reclamation of polders.

The current paper describes restoration projects and flood hazard mitigation efforts on the Maruyama River in Japan. The Maruyama River was damaged by an unprecedented flood in 2004. As a result, the importance of flood control measures and the necessity for river improvements became evident. The developed restoration plan was focused on the conservation and creation of the natural environment, while considering the flood control and irrigation functions of the river.

2 Geographic and historical descriptions of the Maruyama River

The Maruyama River, which flows from the Cyugoku Mountains, is located 640 m above sea level and consists of 97 branches. The main river is 68 km long and has a drainage area of 1300 km^2. Figure 1 shows the location of the Maruyama River and a detailed map of the river basin. The ancient Maruyama River had an inlet lake facing the Sea of Japan, with sedimentation from the upper Maruyama River blocking the river mouth. As a result, the Maruyama River basin was damaged by annual flooding. To improve river flow, large rocks were installed at the mouth of the Maruyama River to allow for smooth discharge of water from the inlet lake to the Sea of Japan. The floodplains of the Maruyama River basin changed from marshes to cropland as a result of the structural improvements. The basin of Maruyama River is 86% mountainous and 14% flat land, which is used to cultivate grain. The lower reaches of the Maruyama River have a very gentle slope, 1/9,000, forming an estuary. The upper reaches of the Maruyama River meanders and have a riverbed slope of 1/850 ~ 1/640.

In the past, the Maruyama River basin flooded frequently and the lives of residents were threatened. Large-scale improvements on the Maruyama River

were conducted between 1920 and 1937. Despite these efforts, 16,833 houses were flooded to the floorboards by Typhoon Isewan (Typhoon Vera) in 1959, and 2,508 houses were flooded by Typhoon No. 19 (Typhoon Flo) in 1990. The levees that had been built in the 1920s reduced the damage from flood waters. However, certain levees collapsed due to the flooding from Typhoon No. 23 (Typhoon Tokage) in 2004, and 56 lives were lost and 7,944 houses flooded.

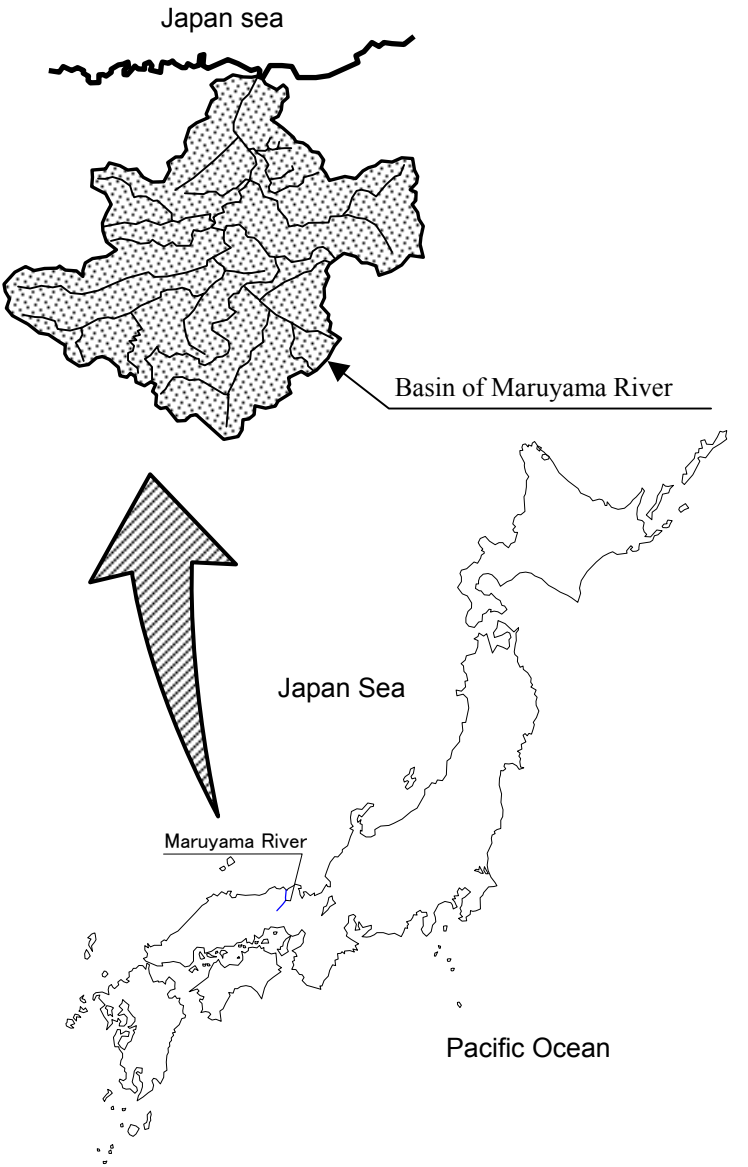

Figure 1: Location of the Maruyama River.

Most of the farmland along the Maruyama River was also submerged by the flood. Figure 2 shows the extent of the area impacted by the 2004 Maruyama River flood, and Figures 3 and 4 are aerial photographs of the devastated.

During the 1960's rice paddy fields were changed to dry rice fields to increase the grain yield. The partitioning of channels and paddy fields for irrigation and drainage deteriorated the fertility of the soil and the river quality. Moreover, extensive losses of paddy fields, channels, and foothills occurred due to the boom in residential land development. As a result, the habitats of various animal species such as loaches, killifish, and storks decreased dramatically. In addition, river engineering projects have straightened and expanded the river width for navigation and have drained adjoining wetlands. The natural configuration of the riverbank and riverbed was lost due to the straightening of the river and the construction of concrete river banks, which caused a loss of habitat and a decline in local populations of fauna and flora. The construction of dams, sluice gates, and pipes destroyed the continuity of the river and the relationship between the river channel and adjacent fields. Furthermore, recent changes in lifestyles have reduced the interest of area residents in the river environment. [2][3].

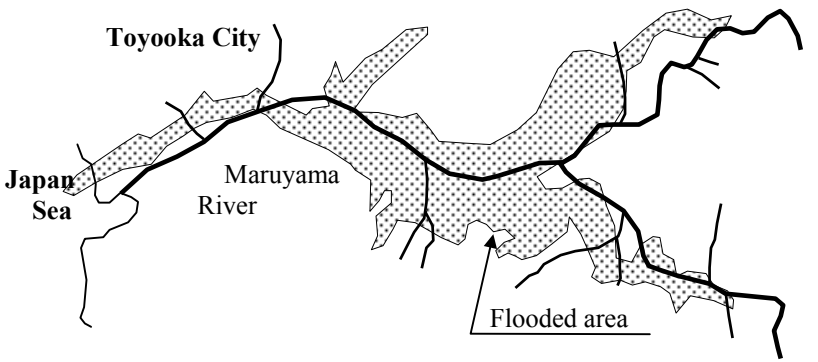

Figure 2: Area impacted by the 2004 Maruyama River flood.

Figure 3: Dike break on the Maruyama River in Toyooka City.

Figure 4: Toyooka City devastated by flooding in 2004.

3 Flood recovery and restoration

Recovery and restoration efforts after flooding must be carried out smoothly, as a collaboration between governments and flood victims. The recovery effort, which immediately follows the disaster, is multifaceted and requires the simultaneous initiation of numerous activities. The activities of primary importance are the identification of impaired roadways and railroads and the reestablishment of road access to the stricken area. The function of waterworks and sewers must also be restored to support remaining residents. Water supply trucks must be provided as an emergency water source. Efforts to prevent mudslides must also be undertaken. Sanitary conditions must be addressed to prevent epidemics and exposure to human and industrial waste. The removal of mud, driftwood, and other objects floating thin flood waters must be initiated. Health care for victims, especially for children, the elderly and the handicapped must be provided, and temporary shelters must be prepared.

The U.S. Federal Emergency Management Agency prepared guidelines for citizens in the period following a flood that address many of the recovery issues listed above. The guidelines included recommendations concerning drinking water, avoiding standing and moving water, avoiding power lines, caution for building entry, and recommendations for cleaning and disinfecting. Communicating such survival guidelines is an important function of the hazard preparation process.

River restoration and mitigation of future flood damages is a long-term process, which involves efficient planning and construction. The rehabilitation of the Maruyama River was planned by the Ministry of Land, Infrastructure and Transportation in Japan in the following manner [4].

Emergency flood control measures adopted for the Maruyama River include soft measures such as the establishment of a disaster information council, providing flood risk information, and enhancing programs to improve disaster prevention awareness. Physical flood control measures included increasing the number of drainage pumps, improving maintenance of the channel, dredging the river bottom, reinforcing dikes, and reconstructing bridges, dams, and reservoirs, as needed.

The plan established periodic improvement goals from 2004 to 2014:

(1) From 2004 to 2005: Structural rehabilitation measures addressed broken areas along the embankment, increased the levee height in portions of the river, and increased the levee height to meet the High Water Level +0.5 m along the embankment section. The non-structural measures that were undertaken were the publication of an inundation map for historical typhoons, assistance in flood hazard map preparation, provision of river images, the design of a system of cellular telephone alerts, the establishment of a Disaster Information Committee for the Maruyama River basin, and the functional enhancement of disaster prevention facilities.
(2) By 2009: The recommended goals were the implementation of reconstruction projects for seriously damaged flood control structures, excavation of the river channel, measures for landslide control, bank

strengthening, reconstruction of bridges, reconstruction of weirs, and the creation of a coalition to evaluate further needs.

(3) By 2014: Completion of the flood control basin project.

The flood hazard map project for Toyooka City in Hyogo Prefecture included the preparation of an evacuation map by individual households. Preparation of the household evacuation map contained four steps, described below.

(Step 1) Assumed maximum flood water depths in the event of a dike break are separated by color on the reverse of the map. Households must identify their residences relative to the assumed flood water depths.

(Step 2) Households must identify their designated shelter and evacuation route, avoiding routes near the river.

(Step 3) Households must rehearse their selected evacuation route and check for hazardous areas along the evacuation route indicated on the disaster map to select a safe and easy route.

(Step 4) Preparation of household evacuation maps, marking the hazardous points and landmarks, and confirming the safest evacuation route must be completed by residents. Two types of signs, "Flood Water Depth" and "Flood Evacuation Shelter" were installed in Toyooka City as part of the "Hazard Mapping Project"

4 Ecological restoration projects in the Maruyama River

Citizens of Toyooka City organized an ecological conservation and rehabilitation plan that focused on the regeneration of habitats and allowed storks to coexist with people. The proposal established an ecological network connecting corridors of water and green space that provided access and movement within the preserve and helped secure ecological diversity [6–8]. This unique ongoing project in the Toyooka City aimed to restore the entire rural region where people and storks once co-existed. The Oriental white stork (*Ciconia boyciana*) was designated a Special Natural Monument, a type of protected species in Japan. The stork weighs approximately five kilograms and has a wing span of up to 4 meters. The stork is a very tall, long-legged wading bird with a long heavy bill, typically with white and black plumage. The white stork has black wing tips and a reddish bill and legs. These migratory birds breed in the extensive marshlands of the Far Eastern parts of Russia and China, and migrate to and from regions along the Yangtze River and Poyang Lake in China. The species is globally endangered, with the total number of individuals estimated at only approximately 2,000. In the past, the Oriental stork could be seen in all parts of Japan. Dozens of storks lived in the Maruyama River Basin, feeding on small fish such as loach, and raising hatchlings in nests built in pine trees near human habitation. The Maruyama River Basin has extensive marshlands and paddy fields that are suitable for foraging by storks [9]. After the Second World War the number of storks declined drastically in Japan due to the environmental degradation that resulted from various social and economic changes. Oriental storks disappeared from the Maruyama River Basin in 1971. The stork was designated a Special

Natural Monument in 1956 and stork breeding farms were opened in 1965. Although three pairs were captured during the period from 1965 to 1968, the last wild stork in Japan died in 1971. Six juvenile storks were donated from Russia in 1985, and the stork pairs were successfully bred in 1989. As a result successful annual breeding, the number of storks exceeded 100 by 1999. The Stork Release Promotion Liaison Council was established in 2002, coordinating the efforts of residents, government, and various industries such as agriculture and fishing to create a habitat for the stork and other marshland species. The liaison council developed the Stork Release Promotion Plan in 2003, and on September 24, 2006, five incubated storks were returned to the wild in Toyooka City [8]. Figure 5 shows a created stork habitat and Figure 6 shows a stork nest.

Figure 5: Stork habitat.

Figure 6: Stork nest.

The Maruyama River restoration project aimed to restore the ecosystem as it was when the stork flourished. In addition to actively improving the habitat, the project focused on educating area residents to value the Maruyama River. Maruyama River restoration project had four goals [3]:

(1) The preservation, regeneration, and creation of distinct natural environments along the river such as meadows, marshes, swamps, riparian forests, foothills, river islands, and stony beaches.
(2) The regeneration and creation of wetlands and paddy fields to provide continuity between land and water, which allows plant and animal populations to succeed.
(3) The maintenance of the channel morphology, and the consideration of aquatic species behavior when installing river structures such as fish ladders and dams.
(4) Preservation and regeneration of the river to support studies of the riparian environment.

Several Maruyama River flood management projects have integrated environmental benefits. To create an alternative pathway for flood waters, the river terrace was excavated in the midstream reaches of the Maruyama River, as shown in Figure 7. As a result, the wetlands along the river shore were regenerated by constructing a shoal along the river terrace (shown in Figure 8) and providing a appropriate habitat for wetland species [10].

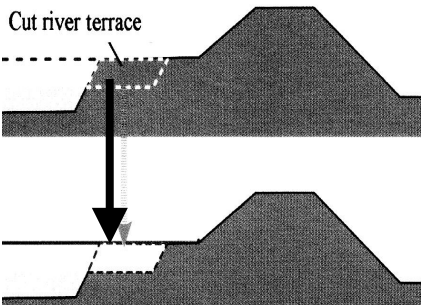

Figure 7: River terrace cut method.

Figure 8: River terrace after cut.

Figure 9 shows Hinoso Island, which is located 1,400 m above the mouth of the Maruyama River and obstructs the smooth river flow. Plans are in place for excavating half of Hinoso Island (Figure 10). Planning for the excavation of Hinoso Island must consider potential habitat disturbance and proceed in a manner that will conserve the island's plants and animals [11].

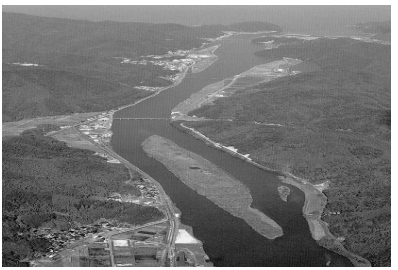

Figure 9: Hinoso Island.

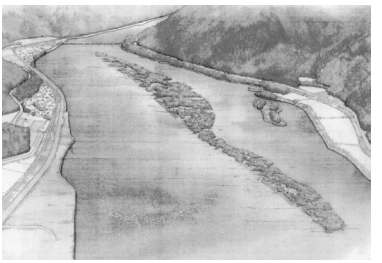

Figure 10: Future profile of Hinoso Island.

Another threatened species in Hyogo Prefecture is the Japanese giant salamander. Certain disaster recovery projects such as the restoration of the river, road facilities and agricultural facilities, may potentially impact the habitat of the giant salamander. As a protected species, impacts to the giant salamander must be considered during the planning and implementation of these construction projects [4]. Several river reinforcement structures have been constructed that accommodate the needs of wildlife. Figure 11 is the Japanese giant salamander that is about 55 pounds and five feet long. Japanese giant salamanders inhabit the cold, fast-flowing mountain stream and rivers of the west in the Japanese Island, eat almost anything they can, from insects to fish to mice to small invertebrates like crabs [12]. Figure 12 shows a weir with fish ladder, Figure 13 shows natural river materials, such as gravel and reeds, and Figure 14 shows a stone masonry revetment built with a fish reef.

Figure 11: Japanese Giant Salamander.

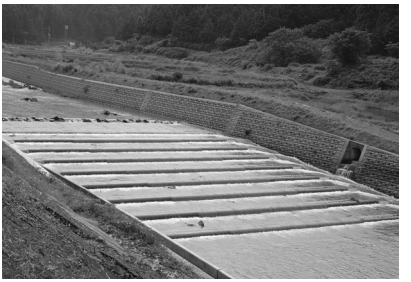

Figure 12: Weir with fish ladder.

Figure 13: Natural river materials.

Figure 14: Stone masonry revetment fit with a fish reef.

5 Conclusions

The disaster recovery projects are still in progress in the Maruyama River basin after flooding due to the 2004 Typhoon Tokage. Environmental conservation and restoration projects, such as the stork release project are being completed by the community and government. Currently, the disaster rehabilitation projects performed in the midstream reach of the Maruyama River will perform two functions, flood control and the regeneration of wetlands, which will provide habitats for the storks. Other measures for restoring the Maruyama River basin include the establishment of breeding facilities for the reintroduction of storks, a review of paddy farming methods and natural restoration of paddy fields. Moreover, the restoration efforts are expanding wetland areas beyond pre-flood size, approximately three times larger. Long-term plans include the regeneration of red pine forests, installation of underground electric cables, and planting wild flowers along rural roads. In addition to the structural measures, Hyogo Prefecture is providing emergency planning information to residents in high-flood hazard areas to prepare for future events. Hyogo Prefecture has enhanced communication with local residents and schools to encourage the active use of this information. As a recent successful recovery project, the Maruyama River basin restoration provides a strong example for future river restoration work in Japan.

Acknowledgements

We would like to thank the citizens of Toyooka City and the employees of the Ministry of Land, Infrastructure and Transport.

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