A study on the comprehensive flood damage mitigation in rapidly urbanizing watersheds

Katsuhide YOSHIKAWA
Foundation of River Front Improvement and Restoration
Ichibancho FS Building Flr., Ichibancho 8 Chiyoda-ku, Tokyo 102-0082, Japan

Junji TAKAYANAGI
Edogawa River Office, Ministry of Land, Infrastructure and Transport Kanto Regional Construction Bureau
134 Miyazaki, Noda City, Chiba Prefecture 278-0005, Japan

Hideaki YOKOUCHI
Foundation for Riverfront Improvement and Restoration
Ichibancho FS Building Flr., Ichibancho 8 Chiyoda-ku, Tokyo 102-0082, Japan

Yuji YAMAMOTO
Foundation of River Front Improvement and Restoration
Ichibancho FS Building Flr., Ichibancho 8 Chiyoda-ku, Tokyo 102-0082, Japan

Yoshiki MOTONAGA
Japan Science and Technology Agency
Kawaguchi Center Building, Motomachi 4-1-8, Kawaguchi-City, Saitama-Prefecture 332-0012, Japan

It is studied integrated flood damage mitigation measures established in the 1980s for the Tokyo metropolitan area (Naka/Ayase River Basin) in Japan and the Bangkok metropolitan area and the entire basin of the Chaophraya River in Thailand, which are representative flood areas in Asia that have experienced dramatic urbanization. The study is conducted from an engineering standpoint and a humanist-sociological standpoint. All the flood control plans are similar in that, as basin measures, they subdivide the basin in terms of the relationship with the river, where possibly preserve retention and detention functions for each subdivision and implement integrated measures combining structural measures such as river improvement. And it is shown that such integrated flood damage mitigation measures are also effective in face of the urbanization expected in Asia in future.

Key Words: River Basin, Naka River, Ayase River, Arakawa River, Chaophraya River, Flood damage mitigation, Bangkok

1. Introduction

It is studied about comprehensive flood damage mitigation measures in regions with rapidly expanding populations based on flood mitigation plans and measures actually implemented in Asian countries that experienced dramatic urbanization, with the aim of helping countries in Asia and elsewhere that have entered an age of urbanization. As the actual flood control measures studied in
this research, Japan’s metropolitan area (Naka/Ayase River Basin and Tsurumi River Basin) and Thailand (Bangkok metropolitan area and Chao Phraya River) were taken, as example of representative flood areas in Asia. The flood damage mitigation measures in all the basins share the same basic idea and actual measures. In other words, as non-structural measures: ① they subdivide the area aiming at the natural retention and retarding function of the basin, ② they mainly guide and regulate development in regions naturally at risk of inundation not only to preserve their retention and retarding functions but also not to increase flood damage potential, and ③ they combine structural measures such as river improvement, and implement integrated measures.

shows the summery of the integrated flood damage mitigation plan in the Bangkok Metropolitan Area as instance.

About the area subdivision, they classify the basin into Retention area, Detention area, and Low-lying area, mainly based on the natural properties such as topographical features and geological features and past actual inundation.

In case of the Naka/Ayase River basin, the Low-lying area is subdivided into further two types, corresponding to the urbanization promotion area and urbanization prohibiting area.

shows a conceptual diagram of the three area (Retention area, Detention area, Low-lying area) in the Naka/Ayase River basin.

A post-evaluation of these flood control measures is conducted and their applicability to regions whose populations will rapidly increase in future is studied.

2. Basic standpoints of this research

It is considered the effects of the flood damage mitigation plans not only from a scientific, engineering perspective, but also from a humanist-sociological perspective. shows both the basic standpoints of this research and the basins studied.

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<tr>
<th>River Studied</th>
<th>Japan</th>
<th>Thailand</th>
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<td>Naka/Ayase River</td>
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<td>Engineering Standpoint</td>
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<td>• Fundraising</td>
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<td></td>
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<td>• Low and legislation, etc.</td>
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<td>• Other</td>
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3. Comprehensive flood damage mitigation in the basins studied

3-1. The Naka River/Ayase River Basin in the Tokyo Metropolitan

1) Profile of basin

The Naka River/Ayase River Basin is in the suburbs of the metropolitan area, and topographically it is the basin of gentle slope rivers on a low-lying plain surrounded by the Ara River (West side), Tone River (North side), Edo River (East side) and Tokyo Bay (South side). The basin area is about 1000km², and the majority of that area is a floodplain of the three rivers (JH).

Throughout the period of high economic growth, the basin (floodplain) became rapidly urbanized as a bedroom suburb for Tokyo.

As a result, due to the development of flood risk zones, and with delays in the construction of flood mitigation facilities, the region was hit by urban flood damage almost every year, and emergency flood damage mitigation measures were urgently needed.

In the basin of Naka/Ayase River, it became clear that the main cause of the increase in flood damage was an increase in damage potential mainly due to the development of areas at risk of flooding. The natural retarding function of the basin was also declined as a result of development.

2) Comprehensive flood damage mitigation measures

In face of such causes of the increase in flood damage, an integrated flood control mitigation plan unifying river improvement and flood damage mitigation measures in the basin, outside the river, was drawn up.

3) Subsequent changes

After the establishment of the plan, urbanization of the Naka River/Ayase River Basin progressed, exceeding the initial development assumption of an urbanization rate of 38% in 1990 and reaching an urbanization rate of 43% in 1995 (See JH). From this diagram, it can be seen that, while urbanization proceeded to some degree in farmland and paddy field areas, since the urbanization of paddy fields was strongly regulated under the Law Concerning Agricultural Promotion Areas, urbanization was curbed to this extent. In other words, an increase in direct flood damage potential due to the urbanization of flood risk zones is also known to have been restrained.

As of 1999, the state of implementation of the plan is about 60% complete on drainage pump stations and just less than about 50% complete for river improvements, and retarding basins. The state of measures in the basin is about 60% complete.

JH compares average total rainfall and inundated area in the Naka River/Ayase River Basin at the time of past flooding. From JH we can see that after implementation of the plan, damage due to flooding in the Naka River/Ayase River Basin has been dramatically reduced. Reflecting such
changes in conditions in the basin after the establishment of the plan, in 2000 the Naka/Ayase River Basin Development Plan was amended.

3-2. The Tsurumi River Basin in the Tokyo metropolitan area

1) Profile of basin

Tsurumi River has its source in Machida City in Tokyo and it is a class A river that runs into Tokyo Bay in the Tsurumi District of Yokohama City. The basin area is 235 km². The Tsurumi River Basin underwent rapid urbanization throughout the high economic growth period from 1965, and while back in 1958 inside the basin the urbanization rate was 10% and the population about 450,000, today the urbanization rate is as high as 85% and the population as large as 1.84 million. (JH)

With the progress of urbanization, various problems arose.

Not only did an increase in runoff and shortening in time to flood arrival occur as a result of a decline in retention and retarding functions in the basin, but outflows of soil and sand as a result of housing development accumulated in river courses, reducing channel downflow capacity, so that flood damage in the basin came to occur frequently.

2) Comprehensive flood damage mitigation measures

Under such conditions, a situation occurred where it was impossible to secure flood safety with the previous approach to river development alone. Therefore, an attempt was made to unify river development and flood damage mitigation measures in the basin. This attempt was systemized as integrated flood damage mitigation measures and in 1981 the Tsurumi River Basin Development Plan was established.

3) Subsequent action

Under this plan there was the installation of disaster-prevention regulating reservoirs as basin measures and large-scale dredging as river measures, so flood safety in the basin increased steadily.

Also, with the aim of not only flood damage mitigation but also the formation of a healthy water cycle in the basin, from 1998 actions began toward the establishment of the Tsurumi River Basin Master Plan.

The aims of this plan are to seek “enjoyment of a comfortable and affluent urban life” and “preservation of the precious natural environment in cities,” in other words, to construct a wholesome relationship between human society and water.
3-3. Bangkok Metropolitan Area, Thailand

1) Profile of basin

Bangkok is Thailand’s capital that opens onto the banks of the Lower Basin of the Chao Phraya River, and it a major city representative of Asia. Flood damage emerged as a result of progressive urbanization in areas that naturally flood (floodplains) and subsidence. Bangkok is a city that developed on the delta of the Chao Phraya River Basin, and topographically, it is the basin of a gentler flowing river on a lower-lying plain than Naka/Ayase River basin described earlier. The floodplain (about 500km²) area in the Eastern and Northern suburbs of Bangkok is the subject of the integrated flood damage mitigation plan.

An increase in damage potential due to development in areas that naturally flood was the basic cause. In addition, since the city water necessary as a result of urbanization was covered by groundwater pumping, there was severe subsidence, making the damage worse.

2) Comprehensive flood damage mitigation measures

As integrated flood control measures the following kind of measures were proposed.

- Outer measures by an outer levee and gates to prevent or reduce flood waters flowing in from the North and East
- Establishment of buffer zone (area preserving retarding function) inside the outer levee.
- A levee was constructed to prevent river water inundation from Chao Phraya River, and floodgates and pumps was established to drain rainwater and flood water inside into the Chao Phraya River.

The urbanization was to be curbed in the buffer zone to prevent the increase of the damage potential, and the retention and retarding function was to be preserved as possible.

3) Subsequent changes

- Before 1983 when the integrated flood damage mitigation measures was implemented, Bangkok was inundated continuously for three or four months. After the 1983, an outer levee (greenbelt) was completed as an emergency measure and drainage pumps (mobile pumps) to the Chao Phraya River.
were also reinforced. Because as a result of these emergency measures inundation was significantly reduced. Months of inundation were reduced to days of inundation. The flood water submergence period in 1986 was two days (5BCMF).

In the Bangkok Metropolitan Area, the population became concentrated and increased and urbanization progressed at a pace that far exceeded initial assumptions. With a population on the scale of 10 million, Bangkok became a megalopolis representative of Asia.

Also the problem of flood disaster as a result of the urbanization that had occurred in the Bangkok Metropolitan Area at the time of establishing the plan can now be said to have expanded not only in the Bangkok Metropolitan Area but also in the Chao Phraya River Basin. The time has come when flood control measures over the whole Chao Phraya River Basin are required, closely related to flood issue in the Bangkok Metropolitan Area.

### 3-4. Chao Phraya River Basin in Thailand

1) **Profile of basin**

The Chao Phraya River Basin is a large basin whose area is about half the land area of Japan (160,000km²).

An increase in damage potential due to the urbanization of areas that flood naturally and the loss of the natural retarding function due to farmland protection and drainage measures and the construction of roads, the increase in flooding downstream resulting from these, have become the main causes of the increase in flood damage.

And if we survey the whole of the inside of the basin, road construction has proceeded rapidly and the lifestyle has changed to a car society and urban lifestyle that cannot tolerate inundation. Also, in areas where floating rice used to be grown, due to the switchover to short high-yield rice, from these quarters also there are now calls for the drainage of farmland.

2) **Comprehensive flood damage mitigation measures**

Based of estimation of flood damage subject to future land use, the integrated flood damage mitigation measures were proposed.

As structural measures in the basin as a whole, three alternatives were proposed and the choice was left to the Thailand government.

<table>
<thead>
<tr>
<th>Year of flood</th>
<th>Duration of inundation</th>
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<tbody>
<tr>
<td>1980</td>
<td>2 months</td>
</tr>
<tr>
<td>1982</td>
<td>2-3 months</td>
</tr>
<tr>
<td>1983</td>
<td>3-4 months</td>
</tr>
<tr>
<td>1986</td>
<td>2 days</td>
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Partial protection: Flood control

Flood prevention and drainage measures in the Middle and Upper Basin that have an adverse effect downstream shall be carried out to the extent that they can be absorbed or offset by the effects of flood damage mitigation measures in the lower reaches.

- Elevation of Chao Phraya River dikes
- Diversion channels on the Chao Phraya River (bypassing downstream from Bangkok)

A flood control plan based on these alternatives is likely to be established in future.

3) Future outlook

A flood damage mitigation plan is being considered based on the alternatives and is likely to be approved in future.

4. Comparison and considerations

It has been shown about concrete integrated flood damage mitigation measures in the 1980s in the three basins. The following conclusion was obtained as a result of comparison and consideration about these three basins.

- A common point of the comprehensive flood damage mitigation measures in the three basins is that they are efforts integrating basin measures and river measures.
- The basic approach of the basin measures (non-structural measures) is to reduce flood damage potential by curbing the development of areas that become inundated, to the utmost. The basin measures in the Naka/Ayase River Basin and the Chao Phraya River Basin including the Bangkok Metropolitan Area were established based on this approach. In an urbanized basin like the Tsurumi River, the aim is to control increase in runoff and impoundment depth resulting from development by making every effort to leave retention and retarding area. However, the basin measures cannot be described as having been adequately effective in the Tsurumi River Basin and the Bangkok Metropolitan Area, with urbanization proceeding even after establishment of the plan. This problem arises in close connection with the progress of urbanization. In spite of virtually the same basin measures being drawn up, unlike the Tsurumi River Basin, in the Naka River/Ayase River Basin, comparatively speaking, urbanization was restrained, with an urbanization rate as of 1995 of 43%. This may be because in the Naka /Ayase River Basin there were a lot of paddy fields whose development is restricted under the Law Concerning Agricultural Promotion Areas. Conversely, in the case of Tsurumi River, because there were few paddy fields inside the basin and the majority was hills (farmland, forests), as of 2000 the urbanization rate had advanced to 85%.
- River measures (structural measures) seek to increase the discharge capacity of rivers and to temporarily store river water by means such as river improvements, the development of river channel and drainage pump stations and the construction of retarding basin. Measures for the actual planning and construction of facilities are drawn up according to the features of each area.

From cases of the Naka/Ayase River Basin and the Bangkok Metropolitan Area of Thailand, the river measures can be considered highly effective.

It has been summarized the similarities and features of the content and results (effects) of basin measures and river development under the flood damage mitigation plans in each basin and subsequent changes in the measures in 5BCMF.
In the case of Thailand’s Bangkok Metropolitan Area, later the problem was likely to escalate into a problem that affects the entire Chao Phraya River basin.

Based on the above, although there is considerable difference in the effect, in areas with a rapidly increasing population, flood control measures integrating basin measures, such as curbing increases in damage potential by restricting urbanization in flood risk zones, and river measures are known to be effective. And it has been shown that essentially such integration flood damage mitigation measures are also effective in areas that will undergo progressive urbanization in future.

<References>