京都大学防災研究所年報 第 50 号 B 平成 19 年 4 月
Annuals of Disas. Prev. Res. Inst., Kyoto Univ., No. 50 B, 2007

Recent Flood Disasters and Progress of Disaster Management System in Korea

Sunmin KIM, Yasuto TACHIKAWA* and Kaoru TAKARA

*Department of Urban and Environmental Engineering, Kyoto University

Synopsis

Since the explosive economic development after the 1960s, Korea has emerged as one of the major economic powers in Northwestern Pacific region. However, the same growth in economy accompanied by a drastic change of social system made the country more vulnerable to exterior effects, namely natural disasters. Floods are the most common form of these natural disasters and the property damage by these disasters has continuously increased. This study examines social and scientific responses and countermeasures on historic natural disasters in Korea. By reviewing the recent typhoon and related flood damage of Korea, this study intends to search the way to mitigate flood disaster of both countries.

Keywords: Korea, Typhoon RUSA, Typhoon MAEMI, flood disaster, flood forecasting

1. Introduction

As a by-product of the Cold War since 1945 and the Korean War of 1950, the peninsula has been divided at 38° North Latitude into the capitalist Republic of Korea, or South Korea, and the communist Democratic People's Republic of Korea, more commonly known as North Korea. The total area of the peninsula is 222,196 km^2, similar in size to that of U.K, New Zealand, or Rumania. South Korea possesses 99,434 km^2 or 45% of the total land mass, and North Korea 122,762 km^2, the remaining 55%. As of 2001, the population of South Korea is 48.3 million (North Korea: 22.3 million, estimated) with a population density of 476 person /km^2, which ranks as one of the highest in the world along with Bangladesh, the Netherlands, and Belgium. Annual growth rate of South Korea is around 0.63% and urbanization rate is about 88.1%. The Korean Peninsula extends southward from the northeastern part of the Asian continent between 33° and 43° North Latitude and 124° and 132° East Longitude. The standard meridian of the peninsula is 135°, nine hours ahead of GMT.

Since the explosive economic development after 1960's, South Korea (hereafter Korea) has emerged as one of major economic powers not only in the Northwestern Pacific Region but also in the world economy. Within last four decades, the population becomes double and the GDP has boosted up drastically (see Table 1).

However, the explosive growth of economy with a change of social system in Korea makes the country more vulnerable to outer effect, such as unexpected natural disaster. Floods are the most common form of natural disasters, and the property damage by the disaster has continuously increased. Floods happen almost every year in Korea, especially during the summer monsoon season in which heavy rains and typhoons occur frequently. Severe windstorm events are much less frequent than extreme rainfall events and other type of

Table 1 Social factor's change of South Korea

Year	Population (million)	GDP (billion KW)	Urbanization (%)
1960	2.499	200	39.1
1970	3.147	2,800	50.1
1980	3.744	37,800	68.7
1990	4.341	178,800	81.9
1999	4.736	483,800	87.6

(source: MOCT, 2001)

natural disasters such as earthquake and volcano eruption is negligible.

Among all natural disasters, it has been estimated that the 80% of total property damage, amounting to an average cost of 50 billion KW per year, was caused by floods. Korea experiences one to three typhoons per year on the average, with most events occurring in August and September. Since 1945, 17 major typhoons directly affected Korea. Among them, Typhoon Rusa in 2002 and Maemi in 2003 caused significant damage to both property and loss of human lives. There have been limitations in the ability to predict high-impact weather and fully utilize forecast information for the benefit of society.

Natural disasters happen only when the natural impact encounter certain conditions. Such conditions in this case, are from topographic and geological characteristics, social and economic change, and preparedness for disaster in structural and non-structural aspects. Based on this viewpoint, it needs to consider all those conditions to analyze properly the Korean flood history. This study examined historic natural disaster mainly by flood of Korea by collecting information of the recent Typhoon and related flood damage. This study will be helpful for the societies having such natural disaster to utilize the advances in science and technology, and to meet the challenge of countermeasure to natural hazard.

The organization of this paper is as follow. Section 2 describes the recent history of flood disaster in Korea with an overview on other types of natural disasters. Section 3 focuses on hydrologic aspects related to flood disasters, such as climate, topographic, and geological characteristics. Section 4 focuses on law and administrative system of Korea for flood countermeasures. Section 5 illustrates technical efforts on flood forecasting and warning system of Korea. Then, conclusion section summarizes this study.

2. Recent Flood Disasters in Korea

2.1 Overview on Natural Disaster

Korea has suffered by natural disaster such as heavy rainfall and snowfall, drought, storm and typhoons in almost every year. In recent days, natural disasters are becoming much stronger, and climate change is believed as one of main reasons.

Table 2 shows occurrence time, casualty, and total property losses of recent 20 years on each natural disaster item. Among those items, property losses by heavy rain is 6,300 billion KW (conversion into year 1999 currency). This amount, which is 73% of total property damages, comes from only 37% of the number of occurrence time among overall natural disasters. It says how big the damages are, which caused by heavy rain during summer monsoon season in Korea. Korea's exposure to the other type of natural disasters such as earthquake and volcano eruption is relatively low or negligible.

Although life damage caused by natural disasters is decreasing during the past four decades, as shown in Figure 1, the property damage has increased. Among all natural disasters, it has been estimated that the 80% of total property damage was caused by floods.

Table 2 Human and Property losses by natural disasters in Korea (1980~1999)

	Occurrence Number	Death (person)	Total Losses (billion KW)
Heavy Rainfall	147	2170	6,294
Typhoon	34	1062	1,849
Storm	146	706	237
Heavy Snowfall	21	118	242
Hail	42	22	0.7
Lightning	6	25	0
Tidal Wave	9	3	28
Total	405	4,106	8,650

(source: MOCT, 2001)

Fig. 1 Damages by natural disasters by decade

1) Damages from storms and heavy rains

Korea experiences one to three storms per year on average, with most events occurring in August and September. Typhoons affecting to Korea are mainly generated in the west of North-Pacific Ocean, where the east side of Philippine is, and slowly moving to Northwest as being stronger. Typhoons occur 27.3 times every year in average, and 3.1 numbers of typhoons affect to Korea annually.

Frequent rains also occur due to the East Asian monsoon. This weather system usually lasts for several weeks, during which time heavy rains and flash floods may result in extensive flood damage. In Korea, heavy rain is generally named when a daily rainfall amount exceeds 10% of annual precipitation amount, which is 1,283mm. Severe windstorm events are much less frequent in Korea than extreme rainfall events. However, typhoon normally accompanies windstorm having more than 17m/sec (50~60km/hr) of wind speed.

2) Heavy Snowfall

The cold high pressure from Siberia causes heavy snowfall in winter season. Table 3 shows the recent five years damage caused by the heavy snow in Korea, and it shows the damage is getting increase.

3) Droughts

Seasonal variation of water resources in Korea is comparatively large. Annually, 46.7 billion ton of runoff, which is the 67% of the annual total runoff 69.7 billion ton, happens in summer Asian monsoon season (May to September). Because most small size river except five main rivers in Korea has steep slope and short river length, utilization of water resources is another big issue in Korea. Table 4 shows the recent five years' damages by draught in Korea.

Table 3 Recent five years' damages by heavy snowfall in Korea

Year	Casualties	Property losses	Severe duration
1999	9	15 billion KW	Dec. 18~21
1998	1	34.9 billion KW	Jan. 8~9
1997	2	21 billion KW	Jan. 1~8
1996	37	1.8 billion KW	Feb. 17~19
1995	14	1.7 billion KW	Dec. 23~26

(source: MOCT, 2001)

Table 4 Drought damage records in Korea

Year	Rainfall (mm) May ~ July	Drought Area (ha)	Property Damages (billion KW)
1967	307	420,547	626,615
1968	122	470,422	700,928
1976	369	28,218	42,044
1977	288	60,222	89,370
1981	658	145,457	216,730
1982	301	231,244	344,533
1992	392	31,523	46,969
1994	231	231,569	249,281

(source: MOCT, 2001)

There was another big drought season from March to June in 2001, and total rainfall during that season was only 79.9mm. Special water supply was conducted until June 14, 2001 for 270,560 persons of 83,073 houses, which cover 80 cities and districts.

4) Earthquake

There have been many earthquake-monitoring centers have been equipped in Korea since 1905, and there were 18 seismometers of Korea Meteorological Agency and 50 seismometers of Korea Resources Research Center in 2001. However, there have been no severe damages by earthquake reported in Korea.

2.2 Recent Flood Disaster

Since 1945, 17 major typhoons that reached Category 3 have made direct affect to Korea, although all these had became reduced to Category 2 or below on making landfall. Among them, six of them including Typhoon Rusa in 2002 and Maemi in 2003 caused significant damage to both property and human lives. Historic devastating typhoons in Korea are shown in Table 5.

In 2004 and 2005, Korea had relatively quiet years with almost no loss from typhoons or heavy rain. Typhoon Maemi, the worst catastrophe in the nation's recent past, struck the southeastern part of the Korean Peninsula in 2003, causing insured losses of 650 billion KW. Typhoon Rusa, the nation's second-worst recent catastrophe, hit Korea in 2002 and resulted in insured losses of 150 billion KW (Guy Carpenter, 2002 and 2003).

Table 5 The most devastating typhoons to Korea

Year	Name of typhoon	Economic losses (USD million)	Max. rainfall (mm/h)
1959	Sarah*	NA	NA
1987	Thelma	530	NA
1991	Gladys	260	600
2000	Prapiroon	560	247
2000	Saomai	890	491
2002	Rusa	6,700	871
2003	Maemi	4,800	432

(source: Guy Carpenter, 2003)

2.3 Typhoon Rusa and Maemi

In 2002, Korea was hit by Typhoon Rusa, which at that time was dubbed by the news media as the Korea's worst natural disaster in history, with 246 casualties and an estimated loss of $6 billion. On Sept. 12, 2003 about one year later, Super Typhoon Maemi hit the southeastern part of the country, and it is reported to be the most powerful typhoon to hit the Korean peninsula since records began almost 100 years ago.

Typhoon Maemi caused a total property insured loss of USD 522 million, which is more than three times that of Typhoon Rusa (USD 126 million). However, total economic loss is estimated to be less (USD 3.7 billion) than that caused by Typhoon Rusa (USD 6.7 billion). Clearly, there is an inconsistency when using different methods to measure the loss: economic loss and insured loss. By examining the different precipitation patterns of the two events and the high concentration of insured industrial property in Korea, the inconsistency can be explained and leads to a distinction between "wet" and "dry" typhoons.

The amount of precipitation in Typhoon Maemi (so-called a dry typhoon) was only 50 % of that caused by Rusa (so-called a wet typhoon). There were no reports of rivers overrunning their banks during Typhoon Maemi, which was one of the major loss impact factors in Seoul during Typhoon Rusa. The damage due to Typhoon Maemi was mostly dominated by wind, while claims following Typhoon Rusa were primarily driven by flood (Ye, 2004).

In addition, the track of Typhoon Maemi was closer to industrial areas and consequently gave rise to a greater insured loss than the case with Typhoon Rusa in 2002. Figure 2 and 3 show each representative damages by Typhoon Rusa and Maemi. While the most damages during Rusa were by huge amount of rainfall and consequent flood in upper stream of river, most damages during Maemi were because of strong wind.

Hit by Typhoon Rusa in 2002 and again by Super-typhoon Maemi in 2003, Korea suffered significant property damages and life loss. There are points to be adequately considered for scientific community, decision makers and public on dealing with the high impact from the two typhoons.

[1] After many complained about the slow relief measures after Typhoon Rusa, the administration did not learn from past mistakes and had not carried out effective evacuation actions when Typhoon Maemi hit again one year later. The Korean government is now pursuing several improvements to its disaster management system, and a task force for planning comprehensive flood mitigation measures has been set up under the Office of the Prime Minister.

[2] The climate is changing but policy for dealing with it has not. Climate knowledge should be transferred more efficiently and quickly to the decision makers as well as the public. After these two super typhoon events, the Korea Meteorological Administration fully recognized that the structure of such weather systems and their formation mechanisms are still poorly understood.

Fig. 2 JangHyun reservoir breached and swept a whole village during Typhoon Rusa

Fig. 3 Container cranes in Pusan port destroyed by strong wind during Typhoon Maemi

[3] Rapid urbanization and industrialization but lacking sufficient infrastructure for disaster management were contributed more in property damage and life loss. Especially in rural area, most warning systems are poorly organized, and it became clear that those areas are highly vulnerable.

[4] Although declaring special disaster zones, thereby offering generous compensation, and passing a supplementary budget bill are needed for the victims to be recovered quickly, it is not better

than prevention or an effective warning system of a natural disaster.

[5] By analyzing the media reports on Typhoon Rusa, Kim (2004) pointed out “the mass media, the primary source of disaster information, has not provided objective and accurate facts to prepare the storm”. Based on the information he analyzed, only 2.1 percent of the stories were considered to be in the pre-impact phase of disaster, and about 49 percent of stories focused on damage cited from victims (16%) and government officials (13%) accounts. It was suggested that the media should pay more attention on providing warning information during the pre-impact period and help to improve the disaster prevention system (Kim, 2004).

Korea is constantly hit by typhoons and the floods caused by the torrential rainfall associated with typhoons are the major costly disasters in the country. Although the government and public in Korea clearly understand the forces of typhoons and its effect to the society, there are still many problems and considering points in the disaster countermeasures.

Dealing with natural hazards is not just a problem of scientific technology or government policy. To well prepare for the extreme natural disasters and to prevent damages, not only scientists and government policy makers, but also public and mass media should work together and collaborate to each other.

3. Hydrologic View Points on Flood Disaster of Korea

3.1 Climate and Precipitation

Korea is in the moderately humid zone of medium latitude. It has a distinct seasonal climate, which is defined by dry, cold continental air masses during the winter and humid, warm air masses from the ocean during the summer. Temperature varies widely between summer and winter, and there is regional diversity as well. Distribution of precipitation is more varied than that of temperature. During the rainy season from June to September, Korea receives about 70% of its annual precipitation of 1,283mm. About 18% of the total annual precipitation falls during the dry season from October to March (MOCT, 2003).

The climate of Korea is suited for conifer and deciduous forests, though the relatively unequal distribution of rains have not allowed for very dense vegetation. At present, good forests can be found in mountain areas, where the forests have been protected and managed to a good degree, especially since the 1960’s. Two or three of the approximately 28 typhoons occurring near the northwestern Pacific Ocean every year, influence the Korean peninsula directly or indirectly. When a typhoon is located north of 20°N and west of 140°E, it is expected to influence the Korean peninsula.

Korea is at a disadvantage due to the yearly, regional and seasonal variations of precipitation when it comes to managing water resources effectively. Two-thirds of the annual precipitation is concentrated between June and September. Thus, there are floods in summer and droughts in winter and spring. When it comes to yearly variations in precipitation, there was 2.3 times of difference in 1939 (754mm) and in 1998 (1,782mm). Arial variation is also very large; there is 1.7 times of difference between GyungBuk Province (1,000mm) and CheJu Island (1,700mm).

Korea gets an average precipitation of about 1,283mm annually, which is 30% more than the world average, 973mm. This may seem sufficient for water resources until Korea's high population density is considered. The average annual precipitation per capita is 2,705m^3, which is about 10% of the world average of 26,800m^3.

Average annual precipitation of Korea produces a potential water resources volume of 127.6 billion m^3. However, 54.5 billion m^3 or 43% of it is lost in the form of infiltration and evaporation and the remainder, about 73.1 billion m^3 or 57% is estimated to be annual surface runoff. Of this amount, 49.3 billion m^3 is swept away by floods immediately, the remaining amount of water, 23.8 billion m^3 flows during normal periods.

Table 6 shows the historic maximum rainfall amounts (1hr duration) of Korea. The highest rainfall intensity recoded was 145mm/hr in July 31, 1998 at SunCheon area, where is southern center of Korea. For the largest five 1hr maximum rainfall amounts, low pressure during summer monsoon season was the main reason. Except Namhae, where

Table 6 Maximum hourly rainfall amount

Order	Values (mm)	Date	Area	Sources
1	145.0	1998/07/31	SunCheon	Low Pressure
2	123.5	1998/08/06	GangHwa	Low Pressure
3	118.6	1942/08/05	Seoul	Low Pressure
4	116.0	1999/09/10	PuYoe	Low Pressure
5	112.5	1993/08/21	NamHae	Low Pressure

(source: MOCT, 2003)

Table 7 Maximum daily rainfall amount

Order	Values (mm)	Date	Area	Sources
1	870.5	2002/08/31	GangLung	Typhoon (Rusa)
2	607.0	1987/07/22	SeoCheon	Low Pressure
3	547.4	1981/09/02	JangHung	Typhoon (Agnes)
4	517.6	1987/07/22	PuYoe	Low Pressure
5	516.4	1998/09/30	PoHang	Typhoon (Yanni)

(source: MOCT, 2003)

is located in southern east coast of Korea, the dominant area for the maximum rainfall was middle of Korea, such as Seoul area.

For the daily maximum rainfall amounts (see Table 7), most of the rainfall happened with typhoon, and the areas hit by those maximum rainfall are mostly located in the southern coast of Korea, besides GangLung (east coast side), where was devastated by Typhoon Rusa in 2002. On the other hand, heavy rainfall from low pressure usually happened in west side of Korea, such as SeoCheon and PuYoe area in 1987.

3.2 Topography and River Characteristics

About 70% of the land of Korea is mountainous, mainly to the north and east. Along the southern and western coasts, the mountains descend gradually towards broad coastal plains. Most of the rivers have their tributaries on the north and east sides, and flow into the Yellow and South Seas. Concentrated for the most part off the southern coast are upwards of 3,200 islands of various sizes that provide scenery unparalleled in the world.

The eastern coast of the peninsula runs directly along the skirt of the steep mountain slope range, while the western and southern coast have curved shapes and have wide alluvial plains in places. Thus, the ridgeline of the watershed runs on the eastern side of the peninsula. In general, rivers running to the eastern coast are short in their length and steep in their riverbed gradients. Long stretching rivers with gentle gradients such as the Han River, the Keum River, the Nakdong River and the Seomjin River flow into the Yellow and South Seas in Korea (MOCT, 2002).

The Han-River basin with an area of 26,018 km^2 (26% of the national land area) accommodates about 21 million persons, while the Nakdong-River Basin with an area of 23,817 km^2 accommodates about 12 million persons. Of the 99,408 km^2 of land in Korea, about 20.8% (20,676 km^2) is suitable for cultivation and most of the remainder is hilly or mountainous. Only about 5% of the area is used for building sites, roads and factories.

The largest river in Korea from the viewpoint of basin area and river discharge is the Han River. It has a basin area of 26,018 km^2 and an annual runoff volume of 27.7 billion m^3, which constitutes 26% and 28%, respectively, of the nation's total. On the other hand, the longest river in Korea is the Nakdong River with a river length of 552km. Major characteristics of rivers in Korea is as follows.

The river reaches are relatively short and channel slopes are relatively steep. The river reaches are short and drainage areas are small in Korea compared with other major continental rivers. The channel slopes are relatively steep upstream because of steep mountains and deep valleys in the uplands.

Therefore, floods occur quickly and peak flood discharges are enormous. Due to the topographical conditions and torrential rainfalls, the hydrographs of rivers in Korea are very sharp and peak flood discharges are enormous compared with other comparable rivers in the continent.

The coefficients of the river regime, expressed by maximum discharge over minimum discharge for rivers, in Korea usually range from 100 up to 700. This large variation in the flow discharge causes serious problems in river management concerning flood control and water use.

4. Law/Administrative System for Flood Fights

4.1 History of Water Resources Development

Water resources planning and development in Korea began in the early 1910's under the Japanese colonial period. Research work and water resources development has continued for 90 years with significant changes. There have been four significant phases in the development (NIDP, 2001).

(1) First Phase (1910 - 1940)

The focus of this phase was rather the control of water resources in Korea through small-scale channel improvement projects than water resources investigation. The main purpose of this period was to secure food production.

(2) Second Phase (1941 - 1965)

World War II pushed the whole land of Korea into a production base for the war support of Japan. Hydropower generation for war support was the main focus of the water resources development until 1945. After independence from Japanese colonialism, the Korean War broke out in 1950 and continued until 1953. It destroyed the whole infrastructure of Korea including many water resources systems. In addition, most of the water resources system built during the Japanese colonial period were located in North Korea. There was almost nothing left in South Korea and there were no activities concerning the planning and management of water resources. This absolute poverty was continued until 1965.

(3) Third Phase (1966 - 1980)

The focus of this phase was the construction of multipurpose dams for the integrated control and management of water resources. As a part of the national master plan for the economy and comprehensive land development, the Integrated River Basin Development Plan of the four major rivers was established and systematically implemented . During this period, great successes were achieved in the water resources development and management. The main achievements were reduction of flood damage by 40% as contrasted with the annual average, 90% completion of channel improvements and increasing the municipal water supply from 30% to 60%.

(4) Fourth Phase (1981 - 1995)

After the completion of the Integrated River Basin Development Plan of the four major rivers, the focus has been given to individual basin development. The political changes from centralization into the localization have caused a lot of problems in the development and management of river basin. The achievements during this period were the completion of multipurpose dams and multi-regional water supply systems. However, Korea will prepare for a bright future in the 21st century through adjustments and modifications of the long-term water resources master plan for river basin development and management.

In spite of newly arising problems within every part of Korean society, the achievements in integrated water resources development allowed provision of a stable water supply. This resulted in an efficient utilization of land, stability of agricultural and industrial production and a better place to live in. Water resources development planning has been established based upon the policy of the National Development Plan. Major goals and policies of the previous national development plan are shown in Table 8.

Table 8 National development plan of Korea

Plans	Period	Major goals
First	1972-1981	- Establishment of basis for economic growth
Second	1982-1991	- Balanced development - Improvement of social welfare
Revised second	1987-1991	- Balanced development - Improvement of social welfare
Third	1992-2001	- Regionally decentralized development - Efficient national land use - Improvement of the quality of the living environment - Unification of South and North Korea

(source: NIDP, 2001)

4.2 Progress on Flood Disaster Counteractions

1) Before the 1960's

Before the year 1960, it was difficult to put much effort on flood control because Korea was in turmoil for political, economical and social aspects. Furthermore, economic background was not sufficient to push up much of flood disaster related projects. There was no concrete legislative and administrative system for natural disaster mitigation at that time, and occasion works related to disaster mitigation and recovery was carried only when it was in demand.

2) In 1960's

On July 22, 1961, regular movement for a natural disaster mitigation has began when national construction agency (國土建設廳), former Ministry of Construction and Transportation, was newly founded under the Economic Planning Board (經濟企畵院), former Ministry of Finance and Economy, and carried a flood disaster recovery work on YounJu area (August 21, 1961). On December 30 in the same year, the River Law (河川法) was enacted for the first time in Korea. the Economic Planning Board was reorganized and changed to the Ministry of Works (建設部) on June 18, 1962, and full-scale of disaster related works got started. For flood prevention activities, national scale projects, such as construction of multipurpose dams, river repairing and maintenance, farming area reformulation, etc. were commenced under the major project, economic development planning (經濟發展五個年計畵), and this activity gave such a large improvement in flood control at that time.

3) In 1970's

In the 1970s, the integrate development project for the four main river (Han-river, Nakdong- river, Gum-river, and Youngsan-river), which had prepared since 1969 from the investigation, was finished and started to construct the Namgang, Andong, and Daecheong multipurpose dams. For those projects, insufficient fund was loaned from Asian Development Bank (ADB). The flood prevention activity started in 1972 was on the purpose to reorganize the 197 habitual flood places and more than 90% of main rivers over the whole country. Korea Water Resources Development Corporation (韓國水資源開發公社), which was founded in 1967, was reorganized to the Industrial Base Development Corporation in 1974, and put more efforts to the multipurpose dam construction. The civilian defense fundamental law (民防衛基本法) was enacted under the ruling of the Ministry of Home Affairs on July 25, 1975, and countermeasure action to natural disaster was under the control of the Ministry's civilian defense activity. Counteraction and organization for a natural disaster was reformatted with the civilian defense system.

4) In 1980's

Since the 1980's, magnitude of natural disaster became larger for the explosive economic growth and many rash development with large-scale country development projects, which did not fully consider those effect to natural disasters. However, the flood control projects was continuously going on by continuing the projects started in 1970's, such as construction of five multipurpose dams, management of the four main river basin, agricultural basement development, anti-erosion work, etc. Additionally, new projects, such as the Nakdong river shore development project I and II, the water system flood control, habitual floodplain area development, were started with the second conglomerate country development project (國土綜合開發計畫: 1982~ 1991). Because people's expectation and their demand to the government had increased with the economic growth in the 1980's, government support had increased to the flood disaster prevention and recovery action. Furthermore, big flood of middle area of Korea in 1983 and the damages by Typhoon Selma were so huge and it was beyond the recovery ability based on the existing legislative and administrative system (over 1,000 billion KW was necessary for a full recovery). Since then, the government special support system has started, and the flood in Danyang area of Chungnam Province in 1988 and the Southern Korea flood in July 1989 were the first case of recovery supporting from the main government up to 73%. Before the government special support system works, it was possible to help only up to 43%.

5) In 1990's

The 1990's is the time of big change in the disaster prevention system by the effect of the big flood in Han-river in 1990 and big disaster by Typhoon Gladis in 1991. First, as the type of disaster was getting diverse and the size was getting larger, the disaster prevention system was reorganized to consider the high industrialization and urbanization of the country. "Disaster effect assessment system" (災害影響評價制) was newly established to assess the effect of a certain level of big development project to the potential danger from natural disasters. In 1995, “small size river maintenance law” (小河川整備法) was enacted to consider many small size rivers, which had been out of the care from the government and, for this reason, much vulnerable to flood disaster so far. Repairing local river basins and expansion of flood forecasting and warning system to many rivers were carried during this time. Especially, following the president Kim’s commend saying prepares “the perpetual and overall countermeasure to flood disaster”, “the special task force team for the flood disaster” was temporally organized under the president’s secretary on September 11, 1999, with members of professional civilians and related public officers. The special task force team had activated until the end of December of the same year and issued 199 acting plans, which are still working on with the related government main projects. Following those acting plan, 24,000 billion KW is allocated for the overall flood control activity on each river basin for 10 years (2000~2009). There were 64 regulations that were modified or newly issued, such as the regulation of a pre-consideration on natural disaster when new development project starts, and 8 government sub-systems were reorganized, including “the river basin managing committee” under the government organization to focus on the flood disasters mitigation.

6) In 2000’s

In the 2000’s, flood disasters are getting serious. Especially, tremendous loss by Typhoon Rusa in 2002 brought “the second special task force team for the flood disaster” under the charge of the prime minister. The second special task force team offered to use 42,790 billion KW for 76 new flood disaster related projects for the next nine years (2003~2011). The offered projects include strengthening a flood forecasting system, preparing a fast and complete recovery system, allocation of related jobs between main and local government for an efficient reaction to disasters, etc. Main differences to the characteristics of the existed projects are the change of the flood control concept from ‘the line defense’ that considers only river, to ‘the surface defense’ that considers overall river basin. Additionally, it was suggested to make “central and local disaster countermeasure center” as a permanent organization, which has been temporarily board only when disaster happens.

5. Technical Effort on Flood Disasters

5.1 Flood Warning System

1) Authority Regulations: The River Law, Enforcement Regulation No. 13-1 and 2 (河川法 施行規則 第 13 條 1,2 項)

2) Flood Warning Procedure

- Collecting hourly hydrologic data from 205 rain gauge stations and 96 stage gauge stations in Han-River Basin
- Estimate water stages and discharges on critical locations based on runoff simulations and considering dam reservoir capacity for a possible discharge reduction
- Flood control with dam operation considering rainfall and stage of lower stream
- Issuing flood warning when the expected stage is higher than warning or alert stage

3) Flood Warning

Flood Warning 1st Level (洪水注意報) : It is issued when the water stage at the critical location is expected to be higher than the water stage of 50% of design flood discharges.

Flood Warning 2nd Level (洪水警報) : It is issued when the water stage at the critical location is expected to be higher than the water stage of 70% of design flood discharges.

5.2 Flood Control System

1) Authority Regulations

- The River Law No.25 (河川法 第25條) : River Management Center (河川管理廳) can ask a proper dam operation to the dam operator to reduce a possible flood in the river.
- The River Law, Enforcement Ordinance No. 57 (河川法 施行令第57條): In a flood defense situation, flood warning and dam operation authority are given to the chief of the flood control center

2) Dam Operation Ordering System on a Flood-fighting Situation

When flood is expected by heavy rain or typhoon, dam operation authority is given to the Flood Control Center on the subject basin. There are currently five Flood Control Centers on the five

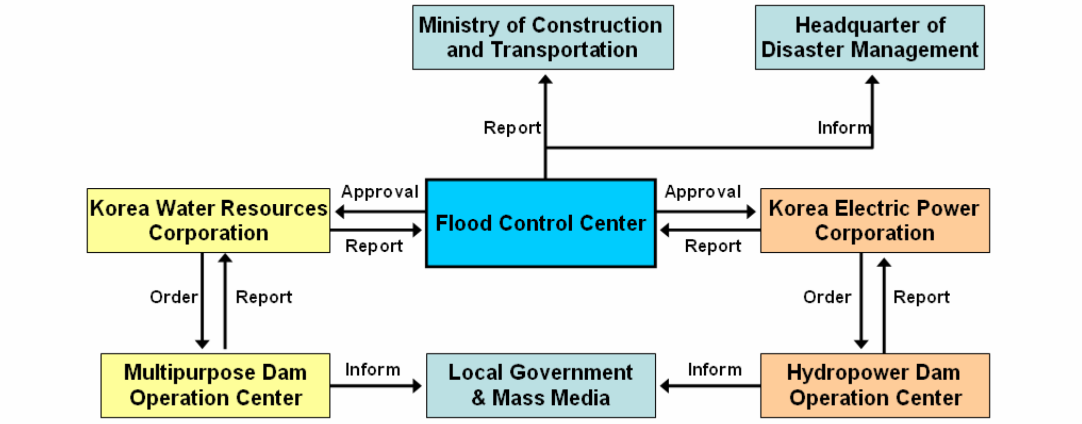

Fig. 4 Dam operation ordering system on a flood-fighting situation

big river basins, Han River, NakDon River, Ghum River, SeomJin River and YoungSan River basin. Among those, Flood Control Center of Han

River works as the headquarters of the other control centers. Flood Control Centers need to report the control situation to Ministry of Construction and Transportation.

For a proper dam operation in a flood preparation, Flood Control Center collaborates with Korea Water Resources Corporation (KOWACO) and Korea Electric Power Corporation (KEPCO) (see Figure 4). KOWACO owns a responsibility for operating multipurpose dams and KEPCO has a responsibility for operating hydropower dams in Korea. For the necessary dam operation during flood-fighting situation, those corporation need to get an approval from the Flood Control Center of the subject basin, and give an order to each corresponding dam operation center. After dam operation center technically operates dam control gates to control outflow from the dam, the operation center reports the results and situations to the corporation and inform to the local government and downstream residents of the dam.

5.3 Disaster Management System

1) Definition on Disaster

In Korea, There are three categories for a disaster definition; natural, industrial and national disaster. Natural disaster is defined as a disaster caused by natural phenomena, and it includes typhoon, storm, heavy rainfall and snowfall, drought, earthquake, etc. Industrial disaster is defined as a disaster caused by accident, and it includes fire, explosion, chemical and biological accident, severe traffic accident, etc. Finally, national disaster is defined as a disaster caused by the malfunction of infra structure, such as energy and water transportation, finance, etc.

2) Authority Ministry and Agency

Each disaster has its own authority ministry and agency for a proper and efficient disaster management in a situation (see Figure 5). In the case of natural disaster, since typhoon and flood can harm any place in the country, Ministry of Construction and Transportation (MOCT) and National Emergency Management Agency (NEMA) manage these subjects. On the other hand, other types of natural disaster, such as drought, cold weather, hail and frost, are highly related to farming or fishery. Therefore, Ministry of Agriculture and Forestry (MAF) and Ministry of Maritime Affairs and Fishery (MOMAF) manage these disasters. For the industrial disaster, Ministry of Commerce, Industry and Energy (MOCIE) and Ministry of Science and Technology (MOST) with MOCT and NEMA are the main agency to control the disasters. Ministry of Health and Welfare (MOHW), Ministry of Finance and Economy (MOFE), MOCT and MOST control national disasters.

3) Disaster Management Procedure

Among many kinds of disaster, flood disaster caused by heavy rainfall and typhoon is the biggest issue in Korea. The Flood Control Center prepared action plan for the case of flood disaster. Figure 6 and 7 describe the management procedure for theflood disaster situations, in the case of heavy rainfall and the case of typhoon, respectively.

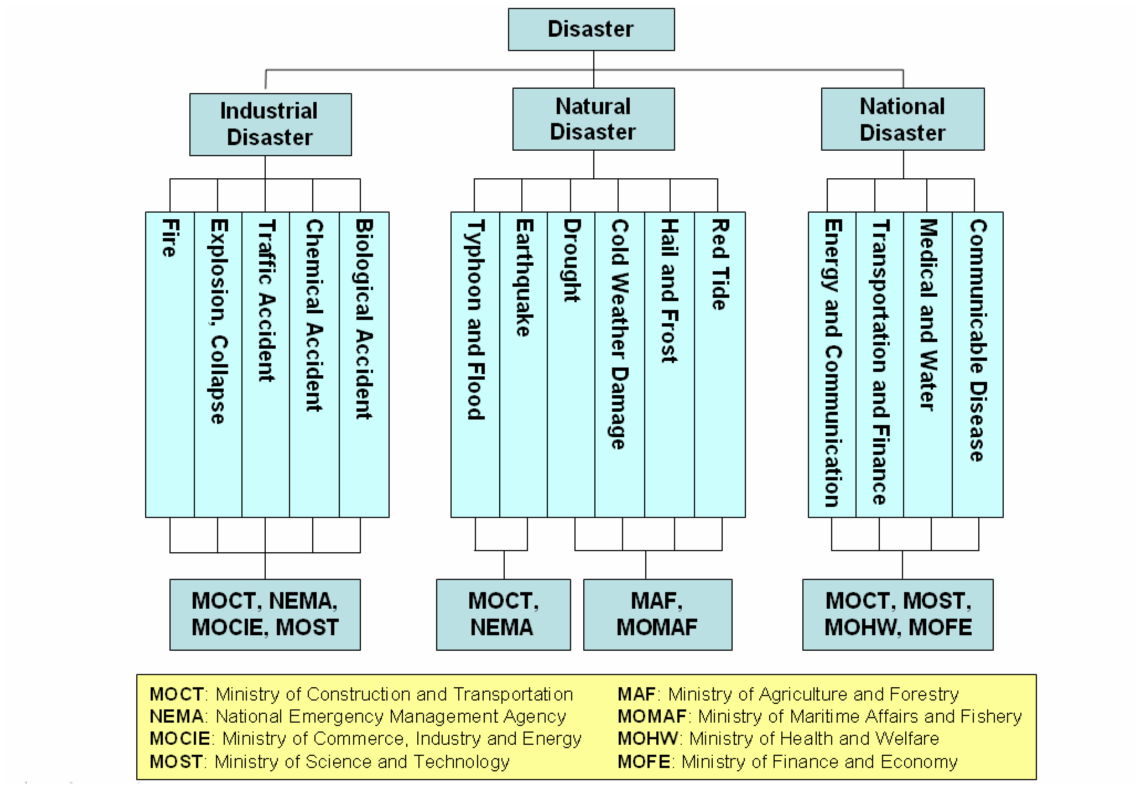

Fig. 5 Authority ministry and agency for disaster management

In the case of heavy rainfall (see Figure 6), the procedure is divided into three steps; readiness stage, warning stage and alarm stage. These steps are classified by the rainfall amount, and damage checking is carried out at each step. The 'readiness stage' is when the rainfall amount was more than 30mm per an hour or 80mm during last 12 hours. At this stage, flood control center orders to allocate observers on the subject river and to distribute flood-fighting equipments. When the rainfall amount was between 30 and 50mm per an hour or 80 and 150mm during last 12 hours, it is classified as a 'warning stage'. At this moment, flood fighters are ready to depart and the local government officers are patrolling dangerous area, such as riverbank, and informing the situation to the residents. If the rainfall amount was more than 50mm per an hour or 150mm during last 12 hours, it is the alarm stage and all public officers should be in ready for any possible situation. All flood-fighters will be departed to the allocated area and rescue equipments are also distributed. Evacuation of local residents is carried in the case of necessary and rescue team is also operating. Even though the rainfall amount was not over the level of each step, water stage on specific point and reservoir volume are continuously checked. At every step, damage checking is carried to survey the human and property losses by the heavy rainfall situation. For more details on the procedure, see refer to Figure 6, and Figure 8 for the water stage checking procedure and Figure 9 for the damage controlling procedure.

Figure 7 illustrates the disaster management procedure when a typhoon is expected on the Korean Peninsula. This procedure is also divided into three steps according to the location and state of typhoon. To prepare the situation, location of typhoon is checked beforehand. If any typhoon is in the area of (N20°, E140°), it is called "1st report area", and the track of the typhoon is checked and informed to offshore ships. If the typhoon is closer to the Korean Peninsula and is in the area of (N25°, E135°), it is called "2nd report area", and the readiness stage begins. At this stage, the typhoon's track is checked and the information is distributed to offshore ships. If the typhoon enters to "special report area" (N28°, E132°), then emergency level

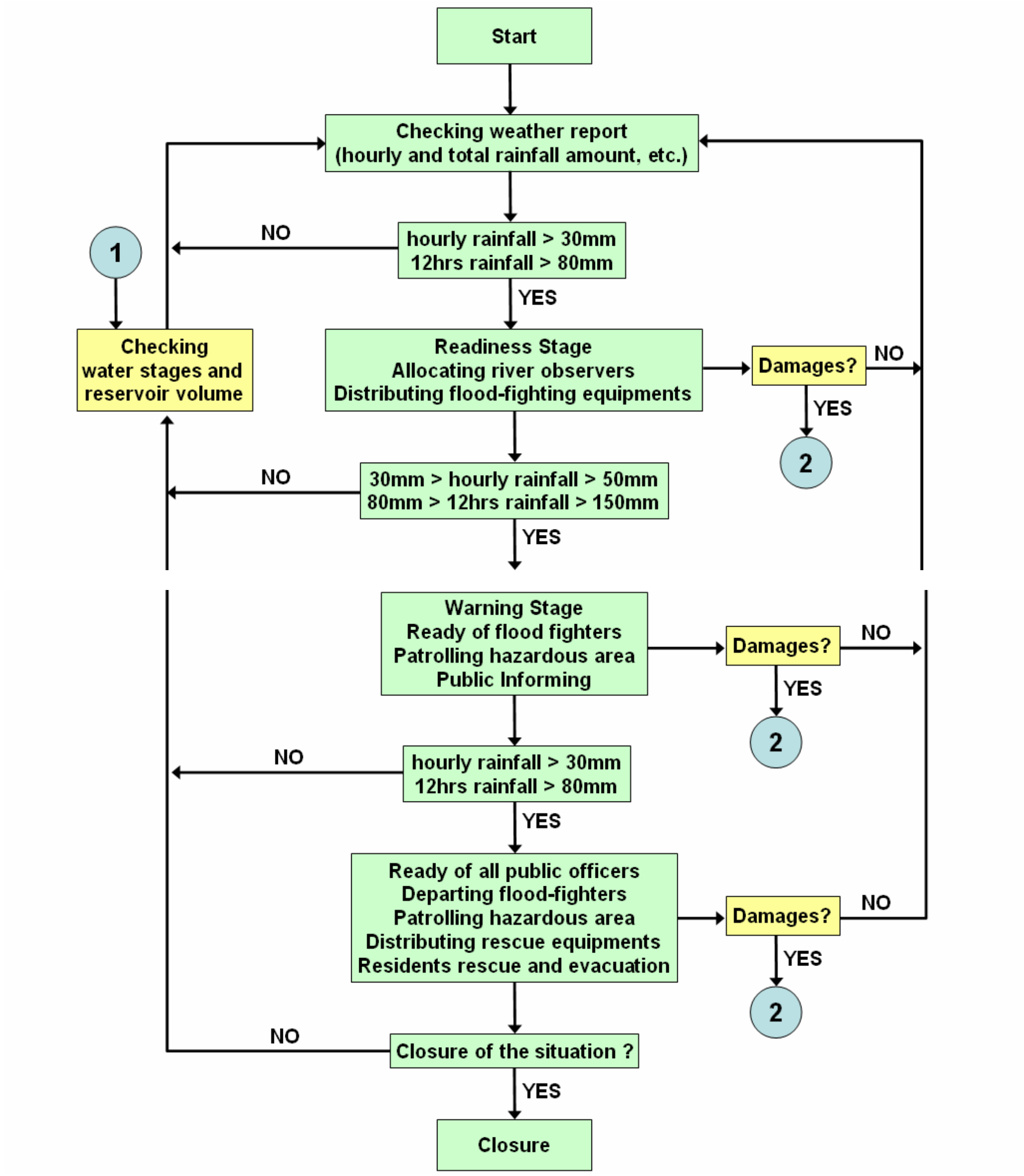

Fig. 6 Disaster management procedure: in a case of heavy rainfall

starts. For the emergency level, possible disaster by the typhoon is prepared; evacuation and tightening of ships, evacuation of coastal area residents, and distributing the information to public. If the typhoon is expected to pass through the peninsula, then alarm stage begins.

Figure 8 describes the procedure for checking water stages and reservoir volume to prepare any flood disasters. If there is any water stage on the flood expected area, the water stage was checked whether it is over 'warning level' and 'risky level'. The warning level and risky level of water stage are pre-decided for each water gauge station from historic data and technical analysis. If there is any dam or reservoir on the subject area, current volume of the dam and the situation near the dam will be considered.

Figure 9 illustrates the procedure for a flood damage counteraction. The counteraction is largely divided into two parts; for life damages and for property loss. In the case of life damages, the damage control helps sufferers, death/missing and injured peoples. In the case of property losses, the counteraction is different to property types; building, farming area and infrastructure.

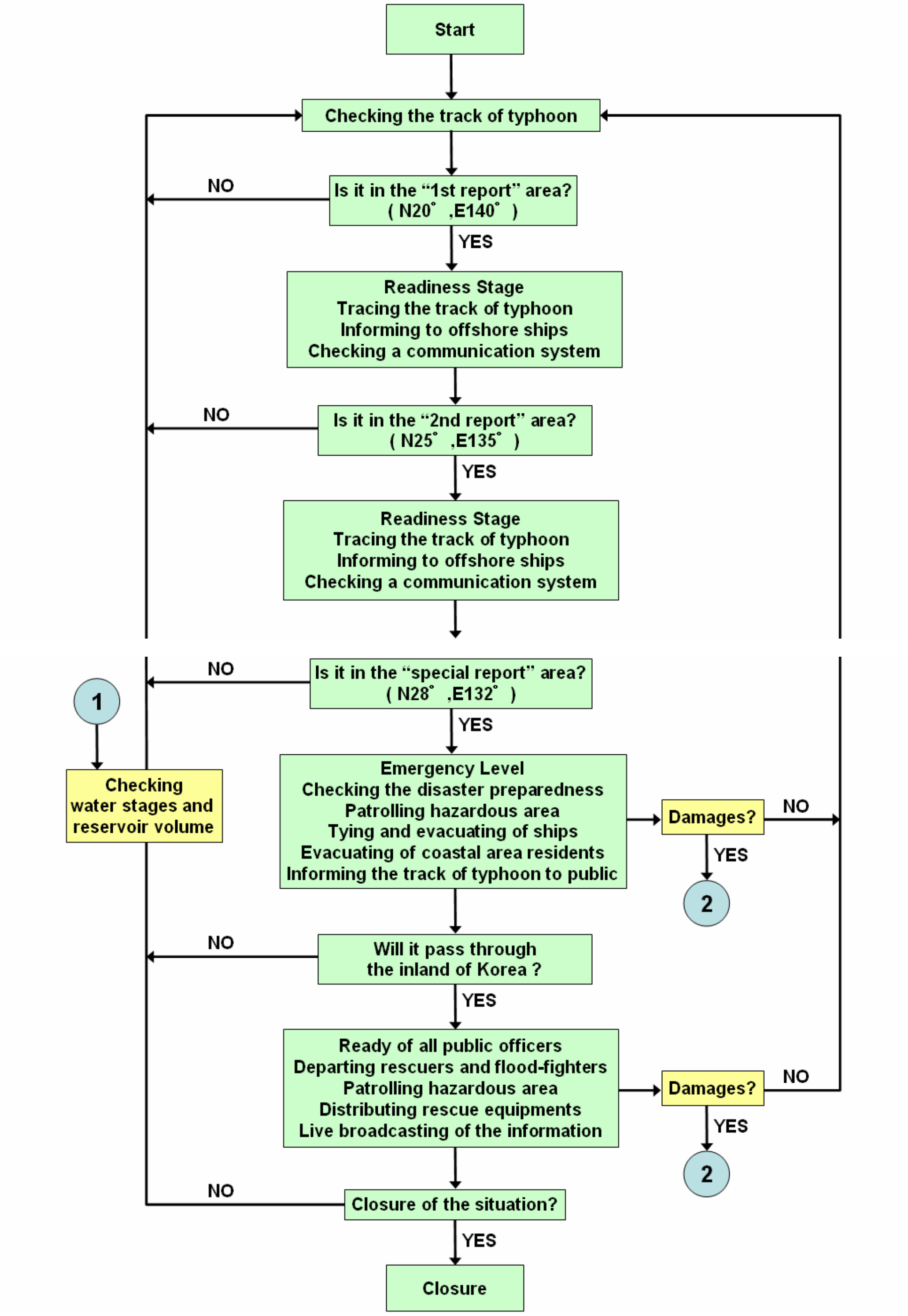

Fig. 7 Disaster management procedure: in a case of typhoon

6. Conclusions

The floods caused by the torrential rainfall associated with typhoons are the major disasters in Korea. The flood disaster in the country seems increase in the near future or at least continues the current pattern. The overall pattern of the natural disaster in the world is also increasing, and the situation in Korea cannot be an exception. Preparedness and counteraction to flood disasters should be more active and progressive in a manner of handling the potential flood disaster threat in the future. In addition to technical and scientific support, the fundamental solution is how the

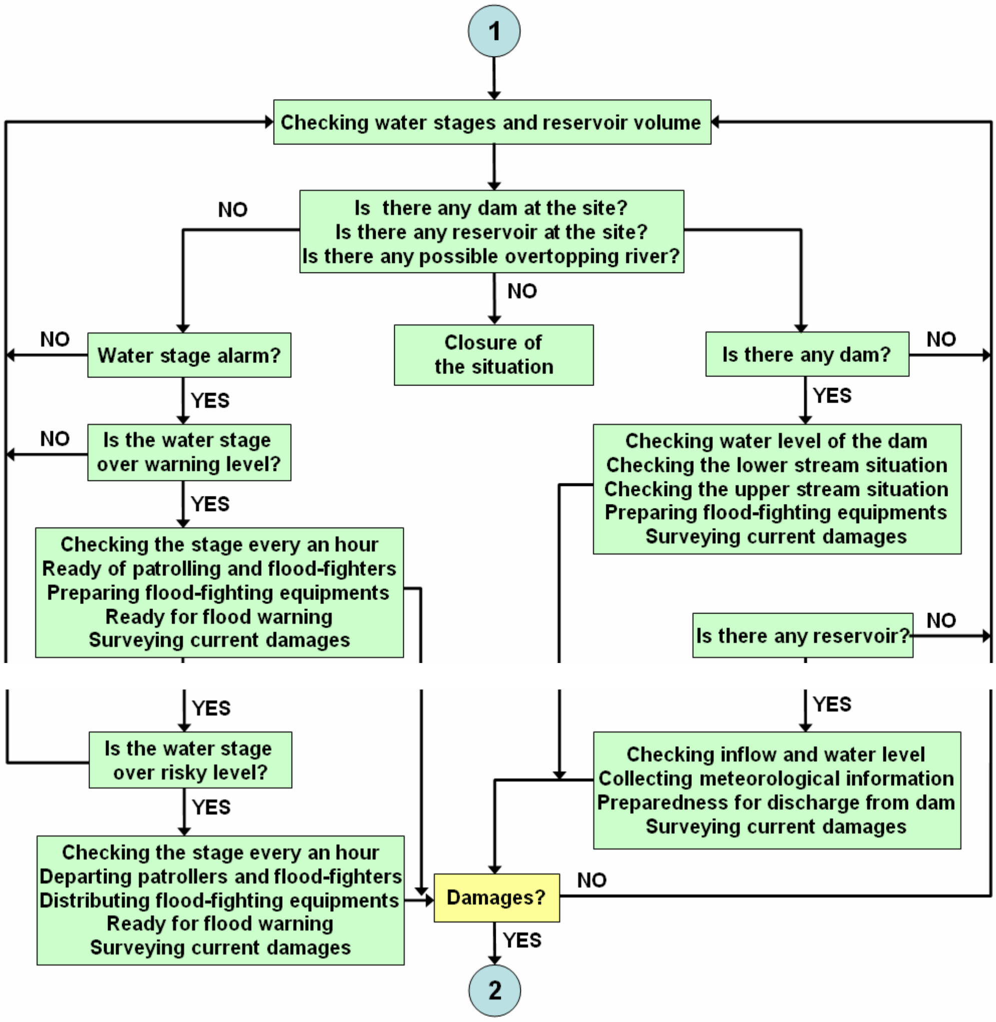

Fig. 8 Dam control procedure in a case of flood and typhoon

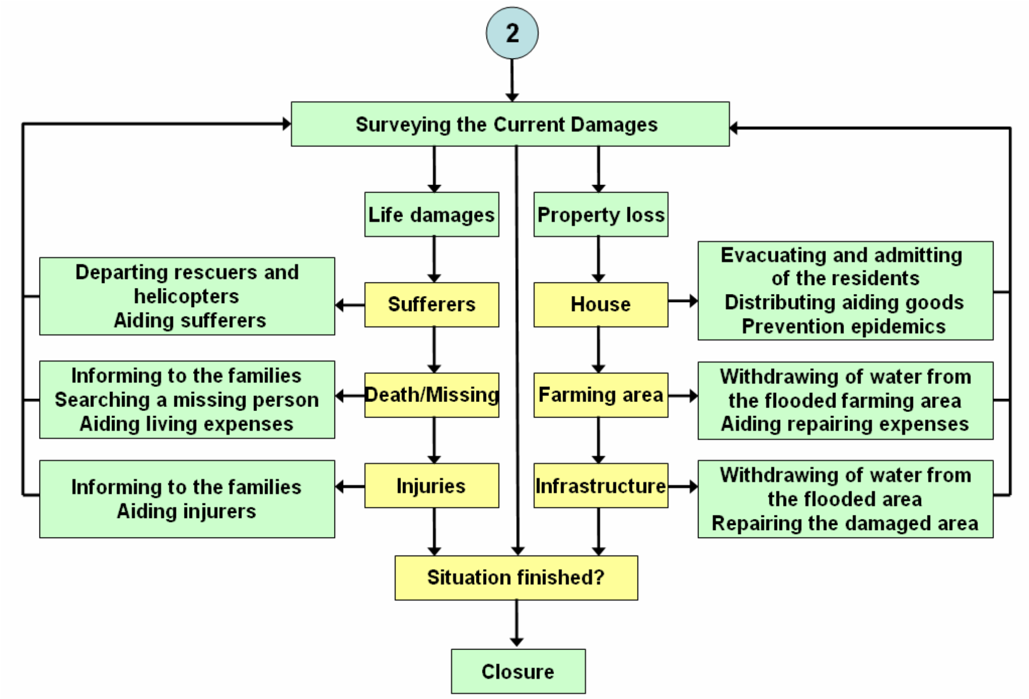

Fig. 9 Damage counteraction procedure in a case of flood and typhoon

government establishes and carries out a long-term plan with an understanding and participation of the people. The direction of the government policy on the disaster countermeasure is decided by the occurrence interval and intensity of disasters, and by the benefit and cost for the policy.

1) Emergency Action Plan: The possibility of the main river breach in Korea is not high, but it is highly necessary to establish an Emergency Action Plan (EAP) for the case of the worst scenario. Recently, there have been many research and preparation on the dam breach EAP in Korea. This is for reducing the possible losses of the downstream of a dam by considering the physical, geographical and structural factors of the dam and its environment.

2) Renewal of Water Resources Management: River embankment and multipurpose dams to control the flood disaster, and any type of reservoir construction to handle the water supply problem have been decided by the frequency analysis using historical hydrologic data. However, the recent climate change and enlargement of the disaster magnitude make it difficult to design the hydrologic structures.

- Concerning flood control: The size of the design flood should be renewal and hydrologic structures are to be reorganized following the reanalysis. The accompanying counter actions for the renewal include structural renewal, such as revision of the riverbank and flood pond construction, and non-structural renewal, such as, flood forecasting and warning system, establishment of disaster proof urban plan and distribution of flood hazard map.

- Concerning drought problem: To maximize the efficiency of the water supply from the existing reservoir, optimization of water supply is highly recommended as well as a consideration on the water supply enlargement and water recycling.

- Concerning an uncertainty in the design flood: Hydrologic uncertainty mainly resulting from the climate change needs to be considered when designing the hydrologic structures.

- Connection of the flood and drought problem: Dam operation and minimum discharge through a downstream channel should be considered together for a comprehensive flood and water supply control. Rainfall infiltration and/or detention pond would be helpful for the both flood and water supply control in an efficient way.

3) Civilian Action Plan: Civilian enrollment for the disaster countermeasure should be more strengthen. When disaster happens, the local resident will be there from the beginning. Government should educate the people for the fast and efficient counteraction to disaster including their own evacuation. Master plan for disaster education should be established and it should be distributed to the public through as many as possible way, such as mass media, brochures and internet.

4) Real-time Disaster Warning System: When disaster happens, real-time observations and field survey are very important for the fast and efficient reaction on the disaster. At this moment, most data on disaster comes through reports from local government and mass media, such as TV broadcasting, and it is not sufficient to check the situation on a real-time basis. It is highly recommended to utilize disaster-surveying technology using the state of the art equipments, such as satellite remote sensing and wireless transmission.

Dealing with natural hazards are not just problems such as developing more advanced observation networks or more complicated models that natural scientists must solve but also issues involving decision makers, who make public policy and daily business operation, and general public to understand weather/climate and apply into the decision making processes. To well prepare for “surprises” the weather and climate extremes, which are associated with climate change, brought on society, scientists must work with the government policy makers and planners, business decision makers, public and mass media.

References

Guy Carpenter (2002): Typhoon Rusa Flood Report 2002. (http://www.guycarp.com/)

Guy Carpenter (2003): Typhoon Maemi Loss Report 2003. (http://www.guycarp.com/)

Kim, Manjae (2004): How media response to Typhoon Rusa in Korea, Presented to International Conference on

High-Impact Weather and Climate: understanding, prediction, and socio- economic consequences, Seoul, Korea, April 2004.
Ministry of Construction and Transportation, Korea (MOCT) (2001): The Study on the Basic Course for Prevention of Disaster Policy, MOCT Study Report (in Korean).
Ministry of Construction and Transportation, Korea (MOCT) (2002): A Study for Efficient Management Method of Flood Recovery, MOCT Study Report (in Korean).
Ministry of Construction and Transportation, Korea (MOCT) (2003): Study for the Countermeasures and Long-term Trend Analysis of Natural Disasters in Korea (I) – Focus on Flood and Storm, MOCT Study Report (in Korean).
National Institute for Disaster Prevention, Korea (NIDP) (2001): The Study on the Basic Course for Prevention of Disaster Policy – For Setting up the Basic Plan for Prevention of Disasters, NIDP Study Report (in Korean).
Ye, Qian (2004): Typhoon Rusa and Super Typhoon Maemi in Korea, NCAR/ESG.

韓国における最近の水災害と災害マネジメントシステムについて

キム スンミン・立川康人*・宝　馨

＊京都大学大学院工学研究科都市環境工学専攻

要　旨

韓国は，1960年以降の急激な経済発展以降，北西部太平洋域における主要経済国の一つとして発展を遂げてきた。この経済発展は同時に，社会システムの劇的な変化を引き起こし，自然災害に対して社会は極めて脆弱なものとなった。洪水災害は韓国においてもっとも一般的な自然災害であり，洪水災害による被害は年々増加している。本研究では，近年，韓国で発生した極めて甚大な自然災害に焦点を当て，それに対する社会的対応，科学的対応，そして対策について調査した結果をまとめる。朝鮮半島を襲った最近の台風とそれによる洪水災害を調査し，それと日本の洪水災害を対比することで，洪水災害を軽減するための方策を考えたい。

キーワード：韓国，台風 RUSA，台風 MAEMI，洪水災害，洪水予測