# Climate Change Adaptation Strategies to Cope with Water-related Disasters due to Global Warming

Provisional Translation

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River sector committee of panel on infrastructure development
Subcommittee on climate change adaptation for flood control

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## Introduction

Climate change that accompany anthropogenic global warming (hereinafter referred to as the "climate change") are a serious issue as they are predicted to cause serious and large adverse impacts, including those that may also shake the foundation of people's life, as well as those on ecosystems, water resources, foods, coastal and low-land areas, industries, and human health. In coastal and low-land areas, both the frequencies and scales of floods, sediment disasters and storm surges are predicted to increase due to sea level rise, increased frequencies of heavy precipitation events and frequent attack of strong typhoons. Serious droughts are also likely to increase due to enlarged degree of fluctuation in precipitation. (These disasters are called "water-related disasters".)

The Intergovernmental Panel on Climate Change (IPCC)[1] published its 4th report. The report suggests that nations should take adaptation measures since global warming mitigation measures has limitation and global warming impacts would continue over centuries even when mitigation measures are taken.

The recognition has been seriously accepted by the international community. Some advanced nations have already started systematic measures against sea level rise, such as levee height increase, along with measures for reducing emissions of greenhouse gases. On the other hand, in Japan, which is one of the most vulnerable to water-related disasters among developed countries, thorough investigations on practical adaptation measures against water-related disasters due to climate change have not been sufficiently conducted, and scientific studies have only revealed the impacts of climate change on water-related disasters.

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[1] Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body consisting of international scientists to collect and analyze scientific studies on global warming.

As ensuring the safety and security of people is a basic duty of a national government, the government of Japan must quickly investigate and implement flexible adaptation measures, including early-stage structural measures, to cope with climate change based on long-term vision.

The board for investigating flood fighting measures to cope with climate change was established to analyze and assess changes in characteristics of sediment-related disasters and storm surges, such as frequency and scale, and their impacts on society and to investigate adaptation measures. While discussing, members have realized the need of conducting investigations not only from a single point view of controlling floods but from various angles. Thus, the board decided to determine the basic and general directions of adaptation measures against water-related disasters and has determined the basic contents of the adaptation measures from various perspectives.

The board has held four meetings from August to November 2007, and summarized an interim report on adaptation measures against climate change. Opinions on the report will be collected from a wide range of people in various manners, and the board will continue investigation and will summarize the results.

## I. Common recognition

### Needs of taking urgent adaptation measures

Since 70% of the national land of Japan is mountainous, about a half of the population and three-fourth of the total assets exist in alluvial plains, which account for only 10% of the area. Areas below sea level in the three major bays of Japan (Tokyo, Ise and Osaka Bays) occupy an area of 577 $km^2$, accommodating 4.04 million habitants. In Japan, which is located on the circum-Pacific orogenic zone, mountains are steep, rivers are short and fast, many fracture zones and landslide-prone areas exist; thus, the country is topographically and geologically prone to disasters. The islands are located on the eastern end of the Monsoon Asia, which is marked by high precipitation, receive a mean annual precipitation of about 1,700 mm, which is twice as much as the world average, are on the route of typhoons, and suffer severe climate events such as large hourly precipitation of almost 200 mm. The land is thus vulnerable to floods, sediment-related disasters, and storm surges.

Flood control measures have been taken to conquer the disaster-prone conditions, such as constructing levees and flood storage structures, and have improved the flood safety level.

However, the construction of planned flood control structures has been slow and remains at a low level, only reaching about 60%. (The government's plan is to implement flood control measures against rainfall with a return period of 30-40 years for large rivers and of 5-10 years for small and medium rivers.)

Although the mean annual precipitation is twice as much as the world average, the per capita precipitation is only one-third of the world average, suggesting that there is not abundant water for use. The steep and short rivers of Japan discharge collected water to the sea fast, and the difference between the maximum and minimum discharges is large, making stable water use difficult. As the population grew, demand for water has increased especially during the period of rapid economic growth. Efficient water-use methods as well as steady progress in water resources development have recently been promoted and recovered the balance between the demand and supply of water. However, the range of fluctuation in annual precipitation has increased in recent years, and years with low precipitation have increased, increasing the risk of drought and endangering secured water use.

The IPCC 4th Assessment Report touches upon a situation for which past record of data would not be practically useful since climate change would cause large-scale sea level rise, more intense storms and typhoons, and more serious droughts. Therefore, areas where disaster prevention systems have been planned and executed based on past meteorological data and experiences would possibly suffer devastating damages due to increases in scale and frequency of floods, sediment-related disasters, and storm surges.

Social structures need to be reconstructed so as to enhance further disaster resistance in order to protect the national land by taking measures for preventing coastal erosion as well as those for preventing and mitigating damages during floods, sediment-related disasters, storm surges and droughts. The national government must immediately plan adaptation measures to climate change.

**Adaptation measures and mitigation measures: the two wheels**

The IPCC 4th Assessment Report mentions, " Even the most stringent mitigation efforts [such as ones in the reduction of $CO_2$ emissions] cannot avoid further impacts of climate change in the next few decades, which makes adaptation essential, particularly in addressing near-term impacts." and clearly emphasizes the importance of adaptation measures. Adaptation measures are thus needed to be implemented together with mitigation measures as the two wheels.

**Implementation of adaptation measures: a duty of the national government**

Observed data and prediction results have shown trends of rising sea water level and increased frequencies of heavy precipitation events. Although the phenomena are not or only partly understood, the national government must draw up appropriate adaptation measures by asking opinions of experts before it is too late since it is a basic duty of the national government to seek for the safety and security of citizens. In some advanced countries, the national governments have already decided or started investigating adaptation measures.

**Proposing effective adaptation measures**

Effective adaptation measures should be proposed by investigating the impacts of climate change, conducting investigations from rational, efficient and effective viewpoints, and aiming for minimizing damages, such as avoiding destructive damages.
In addition, adaptation measures should be designed, considering issues and problems of existing flood control structures, to improve flood control measures in country for the safety of the society.

**Introducing flexible approaches**

Adaptation measures should be planned using a flexible approach by which adaptation measures will be revised based on future observation data and accumulated knowledge about impacts of climate change on sea level, precipitation and river flow.

Thorough consideration should also be paid on social conditions, such as population decrease, aging of population, decline of birthrate, and changes in land use, and circumstances related to water-control works, such as available funds, improvement levels of structures, and water-control plans and works taken in the past.

**Contributing to the international communities**

Floods, droughts, sediment-related disasters and storm surges caused by climate change occur in global scale and are common issues of all international communities, although the degree of the impacts varies depending on area. Especially, countries in Asia and along the Pacific have climatic and geological conditions similar to those in Japan as they are located in the Monsoon Asia and have their production and living bases on alluvial beds. In most of the regions, population is rapidly growing, and water-related problems are becoming more serious. The experiences, measures, policies, and technologies of Japan should be utilized not only in Japan but also in other countries to contribute to the international communities.

## II. Intensification of external forces and impacts on national land and society

### II-1. Descriptions of climate change in the IPCC 4th Assessment Report

The IPCC 4th Assessment Report by the Working Groups 1 and 2 were published in February and April 2007, respectively, describing changes in air temperature, sea level, etc. and their impacts as summarized below:

**The Physical Science Basis**

- In the past 100 years, the global surface temperature rose by 0.74°C over the long period. The recent 50-year trend is twice as much as that in the past 100 years. The temperature is predicted to increase in 100 years by 1.8°C according to a scenario that assumes the least greenhouse gas emissions and a world in which economic growth and environmental protection coexist in global scale, and by 4.0°C according to a scenario that assumes the largest emissions and a future world of rapid economic growth and emphasis on fossil energy sources.

- The total global average sea level is estimated to be 0.17 m during the 20th century. The sea level is predicted to rise in 100 years by 0.18 to 0.38 m under the lowest emission scenario and by 0.26 to 0.59 m under the highest emission scenario.

- Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the increase in anthropogenic greenhouse gases.

- Snow cover is projected to contract. Widespread increases in thaw depth are projected over most permafrost regions.

- It is very likely that frequencies of extremely high temperatures, heat waves and heavy precipitation events will continue to increase.

- Rises in sea surface temperature in the tropics are very likely to increase the intensity of future tropical cyclones (typhoons and hurricanes) with larger maximum wind speeds and heavier precipitation.

- Precipitation is very likely to increase in high-latitude areas and decrease in most subtropical land regions.

- Anthropogenic warming and sea level rise would continue for centuries, even if greenhouse gas concentrations were to be stabilized.

- Both past and future anthropogenic carbon dioxide emissions will continue to contribute to warming and sea level rise for more than a millennium, due to the time scales required for removal of this gas from the atmosphere.

**Impacts, Adaptation and Vulnerability**

- Increased runoff and earlier spring peak discharge will be observed in many glacier- and snow-fed rivers.

- By mid-century, annual average river runoff and water availability are projected to increase by 10 to 40% in high-latitude areas and some wet tropical areas, and decrease by 10 to 30% in some arid middle-latitude areas and the arid tropics.

- Areas affected by droughts are very likely to increase. Heavy precipitation events are very likely to become more frequent, increasing flood risk.

- By mid-century, coastal areas are predicted to face increasing risks due to climate change and sea level rise. The impacts are projected to deteriorate by increasing anthropogenic pressure on coastal areas.

- By the 2080s, many millions more people are projected to be flooded every year due to sea-level rise.

• It is likely to lose approximately 30% of coastal wetlands.

• Population affected by floods will increase by several million annually.

**[Asia]**

• Glacier melt in the Himalayas is predicted to increase flood events and rock avalanches from destabilized slopes, and to adversely affect water resources in the subsequent 20 to 30 years. The phenomena will be followed by decreases in river flows as the glaciers retreat.

• Freshwater availability in Central, South, East, and South-East Asia, particularly in large river basins, is projected to decrease due to climate change. This, together with population growth and increasing demand arising from higher standards of living, could adversely affect over a billion people by the 2050s.

• Coastal areas, especially overpopulated megadelta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea (and from the rivers in some megadeltas).

• Climate change is predicted to constitute the pressures on natural esources and the environment, associated with rapid urbanization, industrialization and economic growth, and inhibit the sustainable development of almost all developing countries in Asia.

## II-2. Intensifying external forces

External forces are climatic factors affected by climate change, such as precipitation, and resultant phenomena, such as floods, droughts, sediment run-off and storm surges.

### 1. Changes in precipitation

The IPCC 4th Assessment Report was prepared based on global projections. To precisely understand the impacts in Japan and use the knowledge for policy making, investigations are needed using downscaling[2] models, which can precisely simulate the phenomena around Japan.

Future changes in external forces were projected using an intermediate-level scenario despite of uncertainty of results due to the capacities of computers and unknown meteorological factors. Changes in flood discharge were estimated from changes in precipitation.

The rate of change[3] in present annual maximum accumulated precipitation in one day and 100 years later was calculated to be 1.0 to 1.5 using RCM20[4] under the A2-type scenario[5] were used. A calculation using GCM20[6] (Scenario A1B[7]) showed rates of change[8] of about 1.1 to 1.2 in

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[2] Downscaling: Translating predictions of coarse resolutions into detailed resolutions that can reproduce regional climate characteristics

[3] Rate of change calculated using RCM20: (mean of 2081 to 2100) / (mean of 1981 to 2000)

[4] RCM20 (Regional Climate Model 20): A regional climate model for calculating the area around Japan. Horizontal resolution: 20 km # 20 km

[5] A2-type scenario: Assumes a heterogeneous world, in which economy and politics are primarily regionally oriented, trades and movement of people and technologies are limited, economic development is slow, interests in the environment are also low.

[6] GCM20 (General Circulation Model 20): A climate model for calculating the entire globe. Horizontal resolution: 20 km # 20 km

[7] Rate of change calculated using GCM20: (mean of 2080 to 2099) / (mean of 1979 to 1999)

general, 1.3 in some regions, such as Tohoku and Hokkaido and a maximum value of 1.5.

Using the calculated results using RCM20 (A2), the rates of change in 100-year probability maximum daily precipitation in 50 and 100 years were calculated. The rate of change in 50 years[9] was about 1.1 to 1.2, and that in 100 years[10] was about 1.2 to 1.4.

Changes in precipitation in 100 years were predicted using the results. Precipitation in 100 years is likely to be about 1.1 to 1.3 times (1.5 times the maximum) of today's values.

The values were calculated using the projection available today, and efforts should be made to improve projection reliability.

## 2. Increased frequencies of floods

Impacts of the changes in precipitation in 100 years on river flood intensity were investigated. Of Class 1 Rivers in Japan, one river was selected from each area. Flood safety level[11] of the present plans and in 100 years and changes in design flood peak discharge[12] were calculated by multiplying the design precipitation and the ratios corresponding to the rate of change in precipitation in 100 years (1.1, 1.2, 1.3 and 1.5). Flood safety level is

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[8] Scenario A1B: Assumes a world of very rapid economic growth, in which global economy further develops, major revolution will occur in education, technology and some other areas, and a balance across energy sources is emphasized.

[9] Rate of change in 50 years: (calculated values for 2031 to 2050) / (values calculated for 1981 to 2000)

[10] Rate of change in 100 years: (calculated values for 20831 to 2100) / (values calculated for 1981 to 2000)

[11] Flood safety level: Degree of safety of a river in flood control plan

[12] Design flood peak discharge: Maximum discharge of the discharge not controlled by dams or other flood control structures

expressed in annual probability of precipitation exceedance[13].

**Flood safety level and design flood peak discharge in 100 years**

The design precipitation[14] in on-going projects was enlarged by the aforementioned ratios, and the annual probability of exceedance was calculated. The calculations showed that an extremely high flood safety level must be ensured in 100 years in order to ensure the present flood safety level, showing the conventional flood control measures alone cannot cope with the changes.

Estimation of 100-year return period design flood peak discharges showed that the peak discharges will increase along with increases in design precipitation but at higher rates. This shows that the larger the changes in precipitation, the larger the scale of flood control measures is needed and thus the more difficult it will be to control floods.

Table 1 Flood Safety Level under Climate Conditions after 100 years

| Rate of increase in design precipitation | Flood safety level (annual probability of exceedance) | |
|---|---|---|
| | Current Climate Conditions | Climate Conditions after 100 years (probability under present climate conditions) |
| 1.1 times | 1/100 | Approximately 1/200～1/300 |
| | 1/150 | Approximately 1/400～1/500 |
| | 1/200 | Approximately 1/500 |
| 1.2 times | 1/100 | Approximately 1/400 |
| | 1/150 | Approximately 1/500～1/1,200 |
| | 1/200 | Approximately 1/1,000 |

13 Annual probability of exceedance: Number of years in which an event occurs once. For example, precipitation of 1/10 in annual probability of exceedance is a rain that occurs once every 10 years or heavier.

14 Design precipitation: Precipitation used for drawing up flood control plans. Duration of a rain event and precipitation during the event are determined.

**Flood safety level of the present plans**

Degradation of current projects' flood safety level was calculated based on the projected changes in 100-year return period of precipitation. The results clearly showed that the safety levels dropped sharply, suggesting that floods and inundations will be more frequent.

Table 2 Impacts of Changes in Precipitation after 100 years on Flood

| Rate of increase in precipitation | Flood safety level (annual probability of exceedance) | |
|---|---|---|
| | Current Climate Conditions | Climate Conditions after 100 years (probability under present climate conditions) |
| 1.1 times | 1/100 | Approximately 1/50～1/60 |
| | 1/150 | Approximately 1/70～1/100 |
| | 1/200 | Approximately 1/100 |
| 1.2 times | 1/100 | Approximately 1/20～1/40 |
| | 1/150 | Approximately 1/40～1/80 |
| | 1/200 | Approximately 1/60 |

**3. Violent debris flows and landslides**

Climate change will alter the temporal and spatial distribution of precipitation and possibly cause increases in short-period and total precipitation, which may trigger debris flows and landslides. The changes are also possible to accelerate weathering of the ground surface and affect the vegetation on slopes, which are causative factors of sediment-related disasters, although the impacts are yet little understood.

Possible impacts of climate change on sediment-related disasters include increases in frequency, changes in time of occurrence, and increases in scale. Increases in frequency may expand landslide occurrence areas to areas other than landslide-prone zones; and the frequency of landslides occurring at the same time in different places is also likely to increase. Particularly, unexpectedly heavy precipitation on areas that have infrequently received heavy rain will cause severe sediment-related disasters. The time of landslide occurrence from the start of rainfall event will be reduced, decreasing the time until evacuation becomes necessary. The scale of landslides is also likely to increase. Increased frequencies of deep-seated landslides will increase the amount of landslide mass and the range over which the debris reaches.

Increases in sediment are prone to causing debris floods.

**4. Increased incidence of storm surges and coastal erosion**

The ocean takes a long time to mix; the heat only slowly goes down to depths, causing seawater to expand for centuries. Thus, sea level rise would continue even if greenhouse gas concentrations were to be stabilized.

Since sea level rise are strongly affected by natural factors, such as multi-decadal changes in atmospheric flow and changes of the Japan Current, it is technically difficult to precisely estimate the degree of rise in each region, but the general impacts of the phenomenon, which is relatively stable over a long period, can be taken into account for designing structures.

As the intensity of typhoons increases, sea level is likely to rise due to their low atmospheric pressures, and the winds will cause strong drifts and high waves. Thus, intensified typhoons, besides sea level rise, are likely to increase damages caused by storm surges and coastal erosion.

**5. Increased risks of droughts**

Japan has faced some low precipitation years since 1965. Precipitations in 1973, 1978, 1984, 1994, 1996, and 2005 observed far less than annual average precipitation, resulting in droughts. The difference between abnormally low precipitation and abnormally high precipitation has expanded in recent years. Future climate change is possible to cause large-scale droughts equivalent to or even sever than one in 1994. Trends of decreased snow cover and earlier snow melt are also likely to be enhanced.

The actual water supply capacities of dams in Japan are possible to become lower than the design supply, failing to provide stable water for urban and other uses. In areas where people depend on snowmelt for water for agriculture and other purposes, climate change is possible to cause serious impacts on water use during and after spring.

## II-3. Impacts on national land and society

Floods, sediment-related disasters, storm surges due to climate change will have huge impacts on the national land and society, but the impacts will vary depending on the topography, river morphology and social and living conditions in basins. Thus, adaptation measures should be investigated for each basin and by dividing a basin into upper, middle and lower reaches and coastal zones. Appropriate measures differ depending on zone, as described in the following examples .

### 1. Upper reaches

In the upper reaches, mountainous regions typically suffer from forest degradation due to the lack of proper forest management which is caused by progressive depopulation and aging of communities in such regions. Therefore, the frequency and scale of disasters which are sediment-related and caused by windfall trees are likely to increase due to heavier precipitation, higher short-time rainfall intensity, and more intensified typhoons. Sediment-related disasters, especially, may cause greater damage due to increases in frequency and scale and changes in the time of occurrence.

More frequent and severer damage by sediment-related disasters will fatally affect mountainous communities, which already suffer depopulation and aging. Such damage will trigger further emigration of younger community members, leading those communities to become extremely aged communities and ultimately to disintegration.

Also, increases in sediment run-off are projected to cause sediment accumulation in flood control structures in the lower reaches, hindering their capacities for flood control and water use. In addition, large quantities of sediment will also accumulate in river channels, blocking flood water flow and thus deteriorating their flood safety levels. Increased sediment run-off will also prolong the period of turbid water.

## 2. Middle reaches

In the middle reaches between mountainous regions and alluvial fans, flooding and inundation are projected to be more frequent due to levee breaches, which are caused by heavier precipitation, higher short-time rainfall intensity, flooding from the upper reaches, and greater sediment run-off. In the middle reaches, floods have been controlled by constructing levees, and the flood plains have been increasingly used for residential areas. Open levees have been closed due to recent land use. In flooding by levee breaches in alluvial fans, flood water will spread over a large area, causing wide-spread damages. Flood waters that flow down steep rivers contain large quantities of sediment and will wash away houses and buildings by their huge energy like debris flows and cause destructive damages. Increases in sediment run-off and the frequency and scale of floods will destabilize the river bed, causing the destruction of structures and structures, such as bridges, and levee breaches, which lead to the infliction of further damage on surrounding areas..

Inundation caused by dyke break will spread to the lower reaches after inflicting different types of damage on locally important cities, industrial parks, paddy fields, and agricultural fields for producing local specialties. When the revitalization of local economies is one of today’s tasks in Japan, floods reduce competitiveness and vitality of local communities and seriously affect local economies.

## 3. Lower reaches and coastal zones

In the lower reaches and coastal zones, where low lands and areas below sea level spread, heavier precipitation, higher short-time rainfall intensity, seal level rise, intensified typhoons, and flood waters from the middle reaches are likely to cause more frequent inundation and flood events due to levee breaches. Advanced urbanization in low lands and areas below sea level has caused larger discharge, making proper draining difficult. Thus, inundation by river and landside waters due to floods and storm surges are likely to prolong over a long period of time. Particularly in the areas below sea level along the three major bays in Japan (Tokyo, Ise and Osaka Bays), the area and population below the mean sea level would increase by about 50% if the mean sea level were to rise by 59 cm, which is the extremist projected value in the IPCC 4th Assessment Report. Greater damages by storms surges are projected to increase in this case.

In many cases, the lower reaches and coastal zones are over populated and have accumulation of properties. Particularly because the three megacities serve as the centers of social and economic activities, floods and storm surges will affect not only the life and assets of people but also cause governmental functions to be paralyzed and international competitiveness to drop.

Also, coastal erosion is advancing in some coastal zones due to drops in the amount of sediment supply. Further sea level rise and intensified typhoons will accelerate coastal erosion and cause sand beaches to disappear. A sea level rise of 30 cm is projected to cause about 60% of all sand beaches in Japan to disappear.

Impacts of sea level rise and intensified typhoons will constitute huge hindrances to national land protection.

## III. Basic directions of adaptation measures

### III-1. Trends of adaptation measures in foreign countries

In October 2007, the European Union (EU) announced the Directive on the Assessment and Management of Flood Risks. The directive requires member nations to assess flood risks based on available knowledge including the impacts of climate change on flood occurrence. It also requires them to prepare flood hazard maps and flood risk maps based on different annual probabilities of exceedance. The directive also calls for consideration of impacts of climate change when preparing and revising flood risk management plans.

In UK, flood safety level against storm surges are projected to drop from once every 1,000 years to once every 100 years by sea level rise due to recent climate change and rapid housing land development. Thus, the Thames Estuary 2100 (TE 2100), which is a flood risk management plan in UK, is being investigated as well as improvement of Thames tide embankment.

In the Netherlands' flood risk management plan, "Room of the River," a total of approximately 7,000 ha is to be secured for retarding areas to cope with increases in the flow of the Rhine. Maeslant Barrier along the Lek River has a structure that can cope with sea level rise in 50 years. Other storm surge barriers have also been designed to cope with sea level rise during their service period.

In May 2006, the Organization for Economic Cooperation and Development (OECD) summarized the activities on adaptation measures against climate change in advanced nations. Adaptation measures are also being implemented and investigated in other European nations, such as Germany and France, the US, Australia, etc.

On the other hand, Asian nations other than Japan are Non-Annex I Parties under the Framework Convention on Climate Change, and only few have included adaptation measures in their national projects mainly due to insufficient adaptation technologies and funds. Of the few, Korea has constructed national policies for securing water and systems for assessing impacts on water resources. For the least developing nations such as Bangladesh, Bhutan, and Cambodia, the National Adaptation Programme of Action (NAPA) is being implemented by the assistance of the Global Environmental Facility and cooperation of the United Nations Environment Program (UNEP) and the World Bank.

## III-2. Basic directions of adaptation measures

### 1. Measures against intensification of external forces

### Change flood control policies

Considering future precipitation increases, the design flood peak discharge needs to be sharply increased if the present flood safety level is to be maintained. The increases are almost impossible to be controlled just by improving river courses and flood control structures because the control itself is technically difficult and the construction takes too long time, regarding social and other conditions.

Keeping the present design discharge would result in severe drops in flood safety level in the future, and the risks of floods and inundation will increase.

To solve these issues, the increment in external forces caused by climate change should be clearly defined in the measures against flood that exceed the design scale or present capacity during improvement (hereinafter referred to as the "over flood").

Therefore, flood control policies should be changed from those that aim to ensure the safety of a river under its design discharge to those that also ensure certain level of safety of the entire basin even during inundation time. New frameworks in which climate change caused by global warming are common phenomena should also be investigated in addition to flexible response to over flood.

### Enhancing measures against intensifying debris flows

As well as measures against intensified debris flows, measures should also be developed and implemented to control sediment in flood waters and mitigate the impacts of accumulating sediment.
Comprehensive sediment control measures for the entire area extending

from mountains to coasts should be enhanced to control and mitigate the impacts of increasing sediment run-off.

**Staged measures against storm surges**

In order to minimize the frequency of inundation which is likely to increase by sea level rise and intensified typhoons, concrete storm surge barriers should be rebuilt higher to enhance their protection capacity against intensified external forces, especially at a time of renewal.

In practice, barrier heights should be raised in stages.
- In the first stage, barriers are to be raised for the height equivalent to the sea level rise.
- In the second stage, barriers need to be raised for the height equivalent to the past sea level rise and predicted or extrapolation future rise to occur during the service life of the barriers.
- In the third stage, rises due to storm surges caused by intensified typhoons are to be included together with the rises determined in the second stage.

The second- and third-stage measures should be taken earlier for areas where the importance of the protected area is high. The concept of structure design should also be revised so as to cope with changes in the external forces acting on the structures caused by sea level rise.

## 2. Deciding clear goals -- Aiming for "Zero victims" --

Since it is difficult to totally protect everything from floods, sediment-related disasters and storm surges which will be intensified by climate change, adaptation measures against climate change need to be investigated aiming for "Zero victims" and to minimize damage. In the Tokyo metropolitan area, another focus is avoiding paralysis of the state functions. Multiple disasters should be taken into account since Japan is prone to earthquakes and volcanic activities. For example, an earthquake may occur after a storm when the water content in the ground and underground water level are high and trigger a landslide. Another goal is to form a national land that has a social environment comfortable to live and harmonizes with the natural environment.

## 3. Basic contents of adaptation measures

Adaptation measures against climate change should be developed by conducting comprehensive investigations on measures to be taken in basin-wide considering role sharing with related organizations and entities. First, the degree to be dealt by structures against an increasing external force should be clarified. Then, the level to be maintained should be determined for each scale of external forces exceeding the capacities of the structures (hereinafter referred to as the "excessive force") in the basin, based on which adaptation measures for minimizing damages are drawn up. For floods, scenarios of adaptation measures appropriate for the inundation pattern in the region should be decided. Possible adaptation measures include revising regional land use and crisis management.

Basic contents of adaptation measures with emphasis on structures, revision of regional land use, and crisis management are summarized below.

### (1) Adaptation measures with emphasis on structures

Structures prevent external forces from causing damage, when such forces are within their capacities, allowing people to engage in regular social and economical activities. This fact shows that it is important to keep improving structural capacities as much as possible.

From a viewpoint of protecting the life and assets of people, preventing and minimizing damages during disasters by constructing and improving structures will continue to be important.

### 1) Maintaining the credibility of structures against changes in external forces

Measures should be developed for maintaining the credibility and improving the quality of structures against assumed changes in external forces by inspecting and assessing the structures.

### 2) Full utilization of existing structures and prolonging their service life

Using the stock of infrastructures that has been accumulated, measures will be taken for effective, efficient, and multi-purpose use of structures, prolonging their service life, and reorganizing and revising their operations in order to thoroughly, efficiently and effectively use existing structures and reduce costs.

Fifty years has passed since the Ise-wan Typhoon, based on which storm surge measures have been designed. Storm surge barriers have aged and need repairing and renovation. Structures built in 1965 to 1975 to cope with the rapid urbanization of the basin and resultant increases in flood incidence will soon need airing and renovation all at once.

Preventive and conservative management methods for prolonging the service period of the structures should be taken together with measures against changes in external forces caused by global warming. It will also be effective to implement such measures when restoring disaster-affected structures.

### 3) Constructing new structures

New structures should also be steadily constructed as well as thoroughly using existing structures from social, environmental, economic and technical points of view.

### (2) Adaptation measures with emphasis on regional improvement such as land use revision

Land use and way of living have changed along with changes in social conditions, such as population decrease and aging of the population. For future communities, not only economic efficiency and convenience but also flood control should be incorporated in systems for reconstructing regional communities.

#### 1) Revising land use and way of living based on changes in social conditions

Land use and way of living should be revised not only in terms of comfort of living but also mitigation of damage from viewpoints of safety and security.

#### 2) Communities adapting to inundation

Communities need to be improved so as to be little affected during inundations by reassessing water retarding basins, secondary levees and ring levees based on land use, arranging new levees in effective places and managing them together with the rivers in order to cope with increases in frequency and scale of floods.

### (3) Adaptation measures with emphasis on crisis management

Intensive facility construction and improvement will be still insufficient for perfectly protecting the land from floods, sediment-related disasters and storm surges. Although such phenomena as sea level rise are relatively easy to respond, other measures are needed to quickly respond to sudden large-scale disasters. Thus, measures against large-scale disasters with emphasis on crisis management need to be implemented together with preventive facility construction.

### 1) Constructing systems for tackling large-scale disasters

Substantial defense systems against large-scale disasters should be constructed by the national government, such as wide-area remedial systems and disaster prevention networks, to strengthen crisis management. The national government and local bodies should cooperate and decide urgent measures to be taken when dyke breaks and/or inundation occurs, measures for discharging flood waters from the flood plain, and quick and appropriate measures during large-scale sediment-related disasters.

### 2) Promoting Non-structural measures based on new scenarios

Non-structural measures should also be promoted along with facility construction. Not only the conventional scenarios but also new scenarios in which changes in frequency and timing of external forces are considered should be used to investigate activities such as information transmission, flood fighting, evacuation, rescue, restoration and reconstruction.

Two-way communication with residents should also be promoted by providing and sharing information related to disaster prevention.

## 4. Important issues for implementing adaptation measures

The scale of external forces, which are to be used as targets in designing structures, and the concepts of safety in basins against excessive forces should be first investigated and determined to implement adaptation measures.

Assessment of external forces and risks, which are the basis of designing adaptation measures, is a responsibility of the Ministry of Land, Infrastructure and Transport. Besides taking actions by the entire national government and building a partnership among related ministries and agencies, a cooperation system among industry, academia and government should be formed to create a framework for collecting new ideas.

Monitoring of increasing external forces should also be enhanced.

## IV. Methods for deploying adaptation measures

### 1. Basic concepts of deployment methods

Since flood control should be executed along with long-range plans, changes in external forces should be appropriately estimated, and adaptation measures to climate change should be incorporated in undertaken flood control policies.

On such an assumption, adaptation measures should be deployed based on the following basic concepts.

#### (1) Taking actions by the entire government

Considering the importance of adaptation measures, the entire government should promote deployment of the measures.

#### (2) Working together with citizens

Participation of citizens is indispensable to planning and executing adaptation measures. The impacts of climate change on floods, sediment-related disasters, storm surges, the national land and society need to be publicized at every opportunity to deepen the understanding of people on the impacts.

#### (3) Predominantly investing in preventive measures

While funds are limited, funds should be predominantly apportioned to structures that are predicted to be most vulnerable and to areas where the population and central functions concentrate.

#### (4) Determining priorities

Program and sites of high priority need to be determined by selecting and organizing measures as well as drawing up a comprehensive set of measures in order to strengthen adaptation measures against climate change with limited available funds.

### (5) Preparing road maps

Short- to long-range policies need to be deployed by setting time axis, including those from short-range viewpoints of five and ten years and long-range policies to be reflected in national land planning. To achieve the goal, clear road maps need to be prepared.

### (6) Adopting flexible approaches

Flexible approaches that involve revising scenarios in accord with accumulation of monitored data and knowledge should be implemented in investigating adaptation measures because predicted climate change contain uncertainties.

### (7) Cooperating with related organizations and bodies

In many basins, for which adaptation measures are comprehensively investigated, goals of the measures cannot be achieved by river managers alone. Thus, cooperation of residents and related organizations is dispensable, together with which river managers should work. For effective implementation of measures, all parties should raise questions and propose possible solutions.

### (8) Developing new technologies and contributing to the international community

New technologies for assessing climate change impacts and adaptation measures should be developed and actively used under collaboration among industry, academia and government. The experiences, policies and technologies of Japan should also be actively dispatched and disseminated to support developing nations and contribute to the international community.

### (9) Promoting researches and studies and reflecting the results in flood control plans

Researches and studies on floods, sediment-related disasters and storm surges that accompany climate change should be promoted jointly with universities and research institutes, and the results should be reflected in flood control plans.

## 2. Procedure for deploying adaptation measures

High-priority themes (III-2.4) on taking adaptation measures should be investigated during the first short-range period, which is the five years until the IPCC Fifth Assessment Report is announced as a summary of a next set of new knowledge. Existing policies that are related to adaptation measures should be predominantly executed.

During the subsequent period (second period), the acts taken in the first period under policies for ensuring the safety of basins against floods should be reassessed. Measures should then be executed according to the resultant priority, and new effective and efficient measures should be taken. The established flood control policies and adaptation measures should be reflected in the Basic River Development Policy and river improvement plans.

After the second period, measures should be designed and implemented in stages so as to accord with changes in social conditions, accumulation of various knowledge as a result of investigations, and changes in condition settings accompanying accumulation of monitored data.

For international contribution, messages should be dispatched to the top leaders of various states, stressing the importance of taking adaptation measures as most important national policies and the need of international cooperation. Advanced prediction and assessment technologies and information technologies should be disseminated, and supports should be given on predicting climate change in Asia and the Pacific using global models and resultant impacts on national lands and society and on planning and executing adaptation measures.

Technical issues involved in designing and executing actual adaptation measures will be summarized separately.

## Conclusions

The IPCC 4th Assessment Report was published, showing more realistic impacts of global warming. Also in Japan, adaptation measures against climate change caused by global warming have been investigated in various fields. The board has discussed the basic directions and practical adaptation measures for avoiding destructive damages by floods, droughts, sediment-related disasters, and storm surges, which are likely to increase in intensity, by considering their impacts on the national land and society.

The basic directions of necessary adaptation measures have been indicated by assuming increases in external forces and impacts on the national land and society although at the moment there are some degree of uncertainties in the global warming scenario, social conditions and predicted climate change . Climate change will seriously affect the land of Japan, which is still weak in flood control, water use and river environment, but we must fight against the impacts by utilizing existing structures thoroughly and taking adaptation measures such as those for basins and that involve reformation of social structure.

Adaptation measures that involve changes in social structure cannot be fully executed by river administration alone, but need to be promoted by the entire government and related ministries with understanding and cooperation of citizens and related organizations.

This interim report was prepared by summarizing discussions made by the board to contribute for full-scale discussion of practical adaptation measures and collect opinions from a broad range of people on social structures and basic concepts of adaptation measures. The report can be dispatched to the First Asia-Pacific Water-Summit, which will be held in December 2007.

The board will discuss practical adaptation measures, including those for droughts, by studying opinions to the interim report and will summarize in a report.