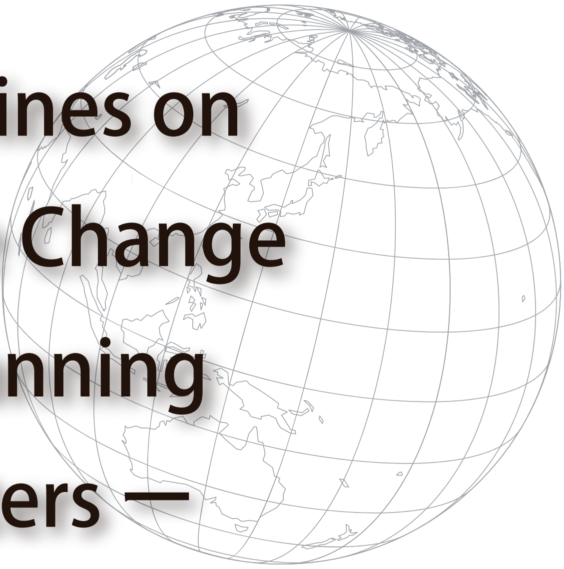
Practical Guidelines on Strategic Climate Change Adaptation Planning

—Flood Disasters —



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Introduction

Climate changes that accompany anthropogenic global warming are a serious issue as they are projected to cause serious, large-scale adverse impacts that may even threaten people’s lives. These impacts will affect a wide range of areas as both the intensity and frequency of floods are expected to increase due to frequent heavy precipitation events, intensified typhoons, and sea level rises.

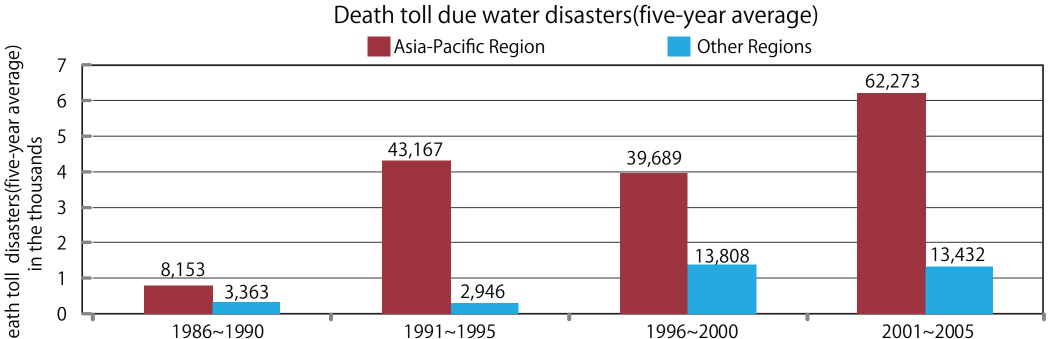
The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) suggests that promoting “adaptation” to the impacts of global warming is equally important as promoting “mitigation” measures. This is because global warming mitigation centered on reducing greenhouse gases such as CO_2 has limitations, and because the impacts of global warming will continue for centuries even after mitigation measures have been implemented.

Impacts of climate change such as increases in the intensity and frequency of floods are occurring worldwide and are common issues for the international community, although the degree of impact varies by region. Located in the Asian Monsoon region, some Asia-Oceania countries have climatic and geological conditions similar to those of Japan, with production and inhabitation concentrated mostly on alluvial plains. In order to organize and implement effective climate change adaptation measures in such areas, it is important to take measures at the state, local government and community levels and to deepen understanding among various stakeholders including policymakers, practitioners, citizens, businesses and scientists and to enhance the ability to adapt.

These guidelines describe a framework for procedures to develop adaptation measures against increasing intensities and frequencies of floods caused by climate change based on experience, strategies and technologies accumulated in Japan. This document mainly targets practitioners engaged in the basin-based management of rivers and water resources in countries in Asia-Oceania and elsewhere where urbanization and land use are expected to intensify because of social and economic progress and population growth; production facilities and people are concentrated in alluvial plains; and effective flood control measures are yet to be developed.

These guidelines address the increase in precipitation and rise in sea level which are expected to lead to an increase in floods. Great importance is attached to estimating future meteorological external forces than the existing flood control guidelines because estimating future meteorological external forces such as precipitation is important to the development of climate change adaptation measures.

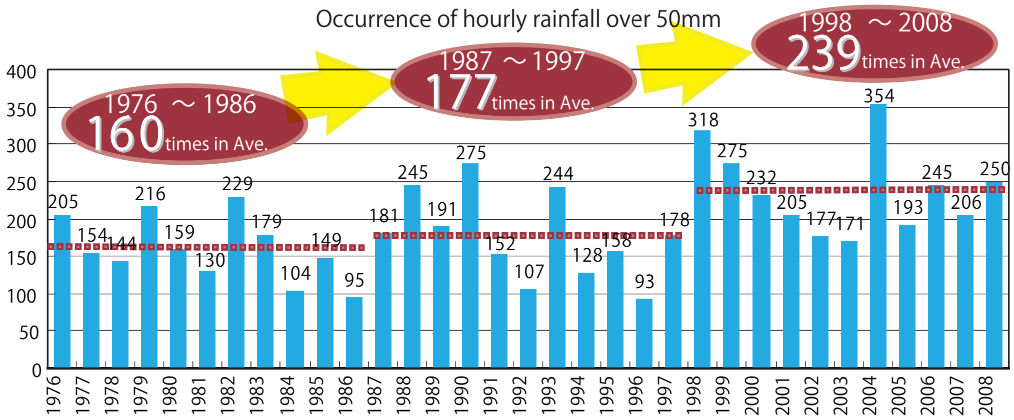
The guidelines have now been compiled, and will continue to be regularly updated by adding detailed explanations to help other countries develop necessary adaptation measures.



Compiled by：Japan Water Forum
Source：EM-DAT, The OFDA/CRED International Disaster Database

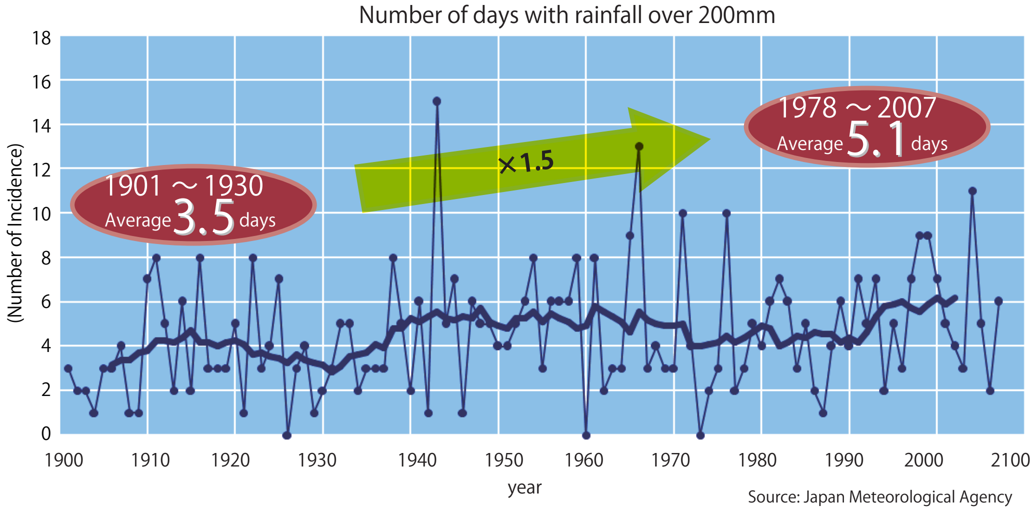
Figure I　Status of flood damage throughout the world

The death toll due to recent water disasters has reached into the tens of thousands per year (more than 80% of deaths are concentrated in the Asia-Pacific region).



- The annual number of occurrence of over 50mm/hr precipitation
- Analyzed with 1,300 national AMEDAS spot data
- Per 1000 spots

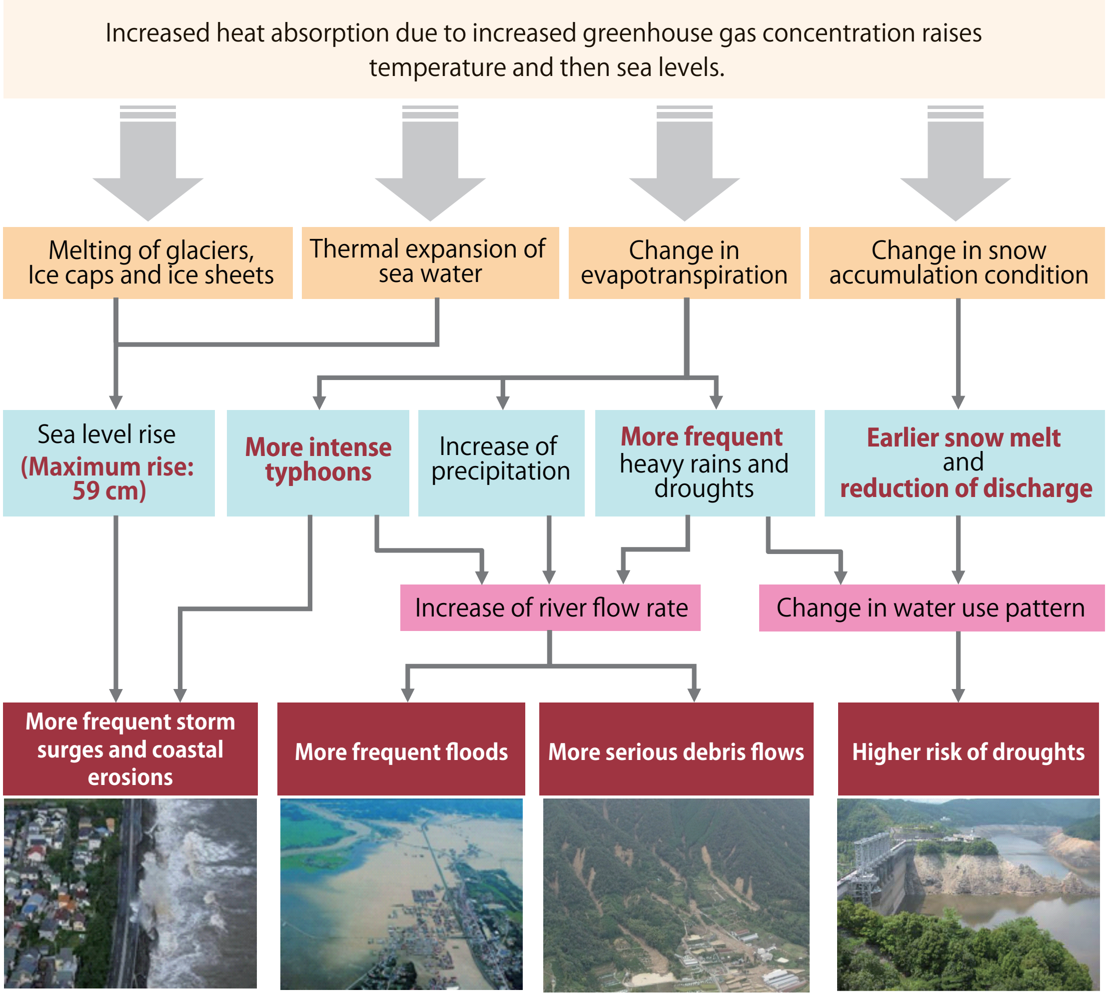
Source: Japan Meteorological Agency



Source: Japan Meteorological Agency

- The number of days with a daily precipitation of 200 mm or more in a year, calculated from precipitations observed at 51 locations in Japan
- Year-to-year values (thin line) and 11-year moving average (thick line)

Figure II　Increase in extreme weather events



FigureⅢ　Global warming threats the water sector

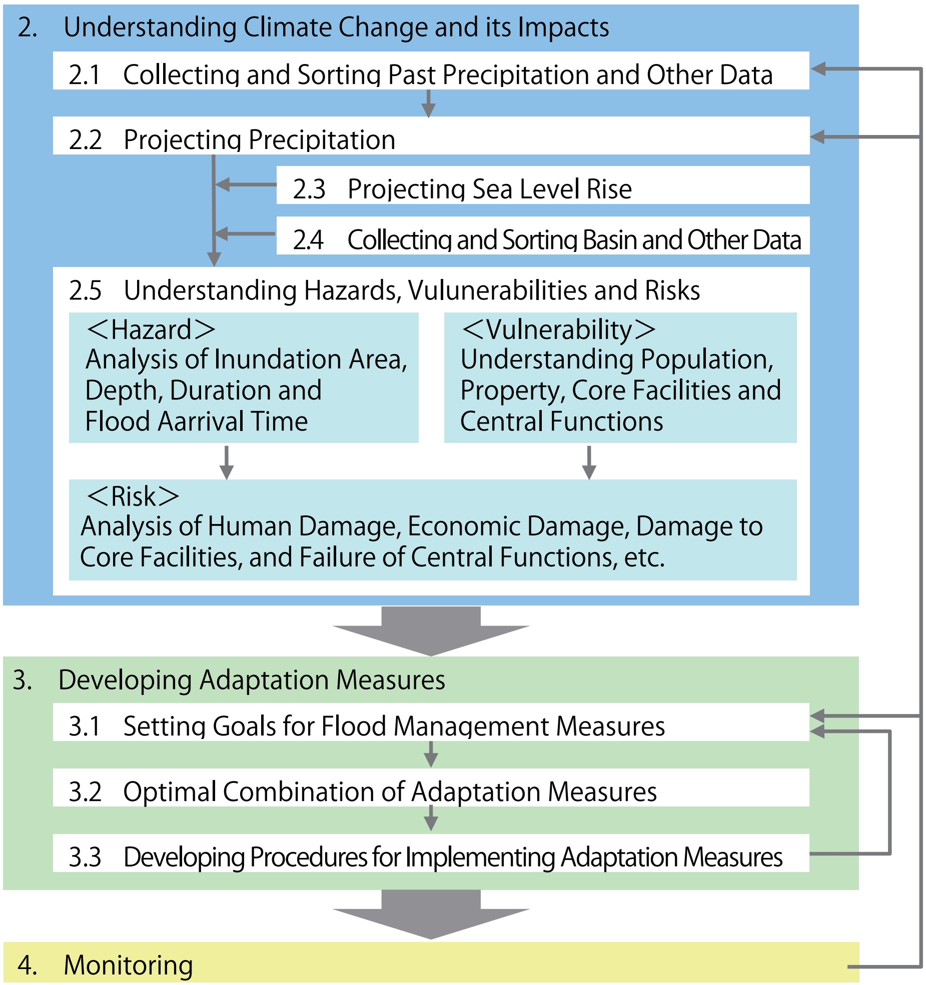
1. Overview

1.1 Purpose of the Guidelines

These guidelines describe a framework for procedures to develop adaptation measures against the increases in the intensity and frequency of floods (excluding storm surges) caused by climate change. The guidelines are intended mainly for countries in Asia-Oceania and elsewhere where urbanization and land use are expected to intensify because of social and economic progress and population growth; production facilities and people are concentrated in alluvial plains; and effective flood control measures are yet to be developed.

1.2 Concept of Developing Adaptation Measures

The flowchart below shows the process for developing adaptation measures.



1.2.1 Flexible Approach through the PDCA Cycle

Adaptation measures formulated based on the methods described in these guidelines need to be flexible in order to adapt adequately to changes, and can be developed by reviewing the results of climate changes and increases in projection accuracy through the PDCA cycle. The PDCA cycle described here includes checks (Check: C) according to the results of monitoring climate changes, as well as checks (C) based on the implementation of adaptation measures (Do: D). When using this PDCA cycle, it is important to fully understand the latest knowledge on climate change, social conditions such as population and changes in land use, development of flood control facilities, and subsequent investment capability.

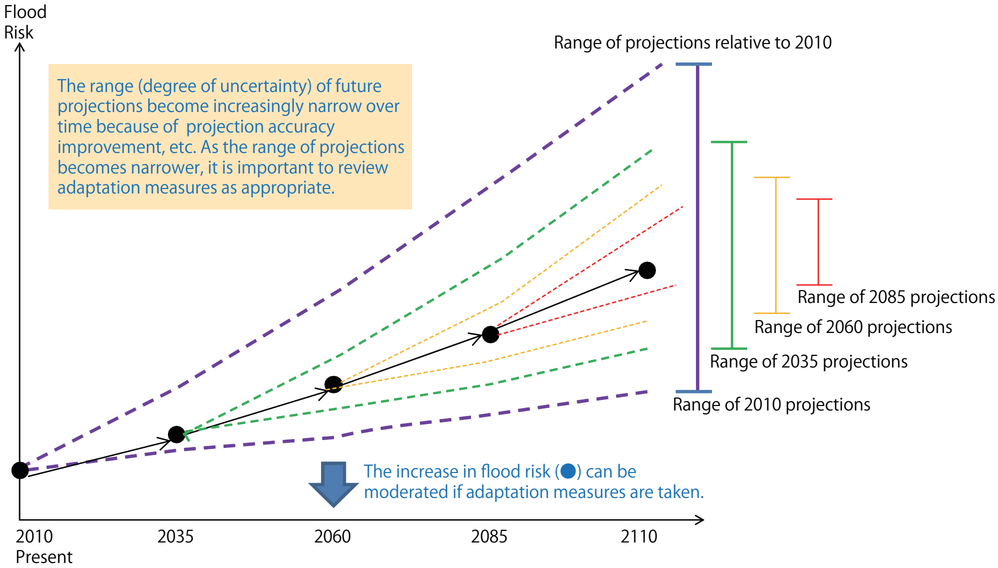


Figure1-1　Concept of treatment of uncertainty

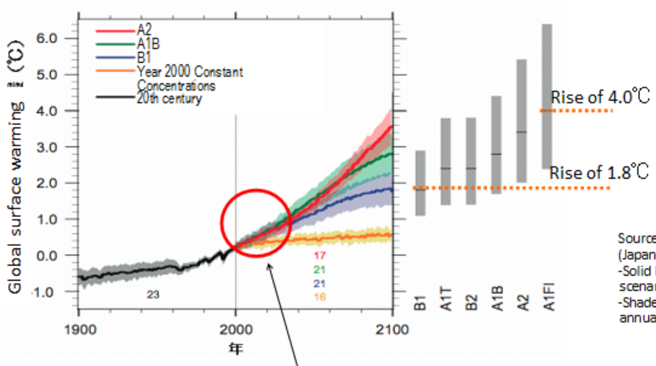
1.2.2 The Target Years for Developing Adaptation Measures

Flood management needs to be developed with a long-term perspective. Considering the years for which projections of climate change are provided, it is necessary to set a target year to consider long-term impacts (e.g. 100 years later) and develop adaptation measures accordingly. However, it should be noted that projection results for 100 years later will greatly differ depending on global warming scenarios. Uncertainty must be considered, as described in 1.3.

Differences in global average temperature projections among the global warming scenarios described in 2.2.3 are small for 20 to 30 years later. At present, it is effective to set a target year to around 20 to 30 years later considering longer-term impacts in order to develop an actual adaptation plan against immediate impacts and to implement it steadily.

It is also important to set multiple target years as necessary as described above in order to avoid setbacks when implementing adaptation measures.

・Average Temperature



A1: High-growth World Scenario
A1FI: Emphasis on fossil fuels
A1T: Emphasis on energy resources other than fossil
A1B: Emphasis on a balance across all sources
A2: Heterogeneous Society Scenario
B1: Continuously Developing Society Scenario
B2: Regional Pluralism Society Scenario

Source: IPCC AR4 WG1 (Working Group 1) Summary for Policymakers (Japan Meteorological Agency)
-Solid lines indicate rises of global average surface temperature in each scenario identified using multiple models.
-Shaded areas indicate the range of standard deviations of average annual temperature for each model.

Differences in 20 to 30 year projections under global warming scenarios are relatively small.

(It is thought likely that global average temperature will rise by 0.6 to 0.8°C over a period of 20 to 30 years from now even if greenhouse gas emissions are controlled.)

Figure1-2　Target years for developing adaptation measures

It is projected that over a period of 20 years from now, global surface temperature will rise at a rate of 0.2° C in 10 years, and it will rise by 1.8 to 4.0° C in 100 years from now. It is also projected that temperature will rise by 0.6 to 0.8 ° C in 20 to 30 years. Differences, therefore, in projections among different global warming scenarios are relatively small.

In order to develop and implement adaptation measures to cope with the impacts for the moment, it is effective to consider adaptation measure to be taken over a period of 20 to 30 years.

1.2.3 Major Steps for Development

These guidelines introduce flexible, adaptive approaches based on the PDCA cycle shown in the aforementioned flow chart. This approach includes: understanding climate changes and their impacts; developing measures based on the climate changes and their impacts; and reviewing the climate changes and impacts based on monitoring results and improvements in projection accuracy as described in 1.2.1.

To understand climate changes and their impacts, first, rainfall data should be collected and analyzed through ground-based, radar, and satellite rainfall observations. Second, an appropriate global warming scenario should be selected from a number of warming scenarios that are based on projected future changes in socio-economic conditions. Under the scenario, rainfall projection required for review should be made based on the projection results of climate models including the Global Climate Model (GCM) through downscaling (space fragmentation) and statistical analysis of rainfall. The projection from such methods may include various uncertainties, and thus appropriate methods should be employed.

Furthermore, projection of sea level rise and data for basins, rivers, and floodplains should be collected and stored.

Then, the hazards, vulnerabilities and risks of flooded areas should be understood. Basic information on developing adaptation measures can be obtained by analyzing how hazards, vulnerabilities and risks of various types of water-related disasters in the future will change from the present situation.

Specifically, the conditions of external forces such as rainfall, the target years for assessment and the development phase of flood control facilities should be set first. Secondly, flood runoff analysis, flood propagation calculation for river channels and inundation analysis should be carried out, so that the discharge and river stage, the area and depth of inundation, time-dependent changes in inundation depth and the duration of inundation can be analyzed.Then, socio-economic conditions such as assets, core facilities and central functions in flooded areas for the target years for assessment should be understood.

These results can then be used to understand and analyze the possibility of occurrence of assumed floods, impacts such as human damage (e.g. number of deaths), economic damage, damage to core facilities and central functions for each inundation block.

When developing adaptation measures, it is necessary to set a general goal for defining the concept for implementing flood management measures for the target years. To achieve the goal, various adaptation options should be planned and evaluated comprehensively in terms of damage reduction effect, cost, impacts on regional society and environment and practicability by risk analysis and other means. Then, the detailed implementation procedure for each option should be set and a road map should be created.

In these processes, measures are taken for reflecting the opinions of residents concerned where considered necessary.

The adaptation measures prepared by such methods should be flexible and updated using the PDCA cycle according to improvements in monitoring results and projection accuracy.

Note that rain is not the only meteorological cause of flooding. Floods may also be caused by increases in streamflow due to the bursting of a glacier lake or snowmelt. Flowing partially frozen water may damage levees, and pieces of ice in river water may dam water. These hazards should also be considered if they can be analyzed by using models for predicting them, statistical data, etc.

1.3 Handling Uncertainties

In general, the methods of climate change projection, hydrological/hydraulic calculations, and inundation calculations have been developed based on dynamic and statistical theories. As the calculation results include uncertainties, highly-reproducible analytical methods should be appropriately selected for respective methods, and the reproducibility of phenomena and the accuracy should be confirmed.

In runoff calculations, an appropriate model should be selected considering the characteristics of each calculation method, the accuracy of data used and the characteristics of basin topography. In principle, the model is identified by using actually measured precipitation and runoff amounts.

In inundation analysis too, it is important to choose a method considering the necessary accuracy, the contents that can be reproduced by each method and calculation time, in addition to inundation characteristics and terrain characteristics of the floodplain and to confirm the reproducibility of past flood records.

Regarding the level of reproducibility and accuracy of methods, it is important to ensure reliability to understand risks and to develop adaptation measures according to the purpose of simulation, the characteristics of each analysis method and the accuracy of data used.

Uncertainties associated with climate change projection include, first of all, uncertainty inherent in the global warming scenarios themselves. This is evident from the fact that a number of cases are assumed in connection with the global warming scenarios. The second type of uncertainty relates to projections made by use of global climate models. This is because there may be differences in projection results among different global climate models. The third type of uncertainty relates to downscaling needed for the reproduction and projection of river basin scale rainfall distributions based on projection results made by global climate models. This type of uncertainty arises because future projections of the spatio-temporal distribution of rainfall to be used in actual runoff analyses vary depending on the downscaling methods used. It is generally thought that uncertainty of this type is smaller than the uncertainty arises from global climate models. Yet another kind of uncertainty exists in the prediction of future changes in floodplain vulnerability (e.g., population, property). When trying to identify risks and decide on adaptation measures, it is necessary to understand in advance that these uncertainties exist.

It is generally thought that a realistic approach when handling uncertainties associated with global warming scenarios or projections of changes in floodplain vulnerability, which are two major components among the types of uncertainties to be considered in connection with climate change projection, is to consider them in the assumption of future changes (or scenarios), that is, to consider them in the selection of a scenario. As a means of treating uncertainties in climate models and other factors, the method for estimating the range of uncertainty in a rational way by using a number of climate models and comparing the result (“ensemble projection method”) is proposed. This method is described in detail in Chapter 2. It is desirable that an appropriate combination of cases be studied at each stage in view of time and funds available for studies on climate change projection.

2. Understanding Climate Change and its Impacts

2.1 Collecting and Sorting Past Precipitation and Other Data

It is necessary to collect and sort long-term precipitation data with consistent quality in order to review the safety levels of current and planned flood control measures, and differences and changes resulting from the occurrence or nonoccurrence of climate change. These data are also needed to review and verify calculation results replicating the present status with GCM, downscaling, and bias correction methods described below.

Observation of precipitation patterns generally includes methods such as ground-based, radar, and satellite rainfall observation.

In order to collect long-term consistent data on total precipitation that may cause flooding and rainfall distribution by time and space, it is desired that a monitoring network of ground rain gauges is installed to obtain rainfall observation data according to the basin scales. If the network of ground rain gauges is not sufficient, rainfall observation data needs to be complemented with rainfall distribution by time/space obtained by radar or satellite sensors. In such cases, the data should be utilized by fully understanding the characteristics of rainfall obtained by radar or satellite sensors.

The International Center for Water Hazard and Risk Management (ICHARM) has developed the Integrated Flood Analysis System (IFAS). IFAS uses satellite-based precipitation data to perform integral analyses, including runoff analysis and calculations of flood propagation in river channels.

Some long-term precipitation data are kept as paper documents; by digitizing the data, it can be used for identifying rainfall characteristics in the target area.

[Reference] APHRODITE

APHRODITE is a long-term daily precipitation grid database system centered on Asia. This database system, called "APHRODITE," is being developed by the Research Institute of Humanity and Nature and the Meteorological Research Institute of the Japan Meteorological Agency. The database contains daily precipitation data obtained from ground-based rain gauges including data that were originally recorded only on paper. APHRODITE integrates daily precipitation data over a period of 57 years (from 1951 to 2007) on a 0.25-degree grid.

(http://www.chikyu.ac.jp/precip/index.html)

【Reference】Climate changes described in the IPCC Fourth Assessment Report

The IPCC Fourth Assessment Report released since February 2007 describes observed changes in air temperature and sea level rise and their impacts as follows.

（Observed climate changes and their impacts）

- Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.
- The linear trend in the 100 years from 1906 to 2005 was 0.74 [0.56–0.92]*° C.
- Rising sea level is consistent with warming. Global average sea level has risen since 1961 at an average rate of 1.8 [1.3 to 2.3] mm/yr and since 1993 at 3.1 [2.4 to 3.8] mm/yr, with contributions from thermal expansion, melting glaciers and ice caps, and the polar ice sheets. Whether the faster rate for 1993 to 2003 reflects decadal variation or an increase in the longer-term trend is unclear.
- From 1900 to 2005, precipitation increased significantly in eastern parts of North and South America, northern Europe and northern and central Asia but declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Globally, the area affected by drought has likely increased since the 1970s.
- It is likely that the frequency of heavy precipitation events has increased over most areas, and since 1975 the incidence of extreme high sea level has increased worldwide.
- Changes in snow, ice and frozen ground have with high confidence increased the number and size of glacial lakes, increased ground instability in mountain and other permafrost regions and led to changes in some Arctic and Antarctic ecosystems.
- There is high confidence that some hydrological systems have also been affected through increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers.

（Projected climate changes and their impacts）

- The best estimate of the increase in global average surface temperature at the end of the 21st century [difference (° C) of the 2090–2099 temperature from the 1980–1999 temperature] is 1.8° C under the scenario assuming global solutions to environmental and economic sustainability and 4.0° C under the worst-emissions scenario.
- Projected sea level rises at the end of the 21st century [difference (m) of the 2090–2099 level from the 1980–1999 level] are 0.18–0.38 m under the scenario assuming the least greenhouse gas emissions and 0.26–0.59 m under the worst-emissions scenario.
- It is highly likely that the frequency of extreme high temperature, heat wave and heavy precipitation events will continue to increase.
- It is likely that the intensity of tropical cyclones will increase. There is low confidence that tropical cyclones will decrease worldwide.

- Extratropical cyclone tracks will shift poleward, and, as a consequence, wind, precipitation and air temperature distributions will also shift.
- Increases in the amount of precipitation are likely in high-latitudes, while decreases are likely in most subtropical land regions, continuing observed patterns in recent trends.
- By the middle of this century, annual river flow and river water availability will increase in high-latitude regions, while they will decrease in the mid-latitude regions and some arid regions. Semi-arid regions will suffer from decreases in water resources caused by climate change.
- Altered frequencies and intensities of extreme weather are expected to have mostly adverse effects on natural and human systems.

〔Asia〕

- By 2050, freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease.
- Coastal areas, especially heavily populated megadelta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea and, in some megadeltas, flooding from the rivers.
- Climate change is projected to compound the pressures on natural resources and the environment associated with rapid urbanization, industrialization and economic development.
- Endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise in East, South and South-East Asia due to projected changes in the hydrological cycle.

〔Small island states〕

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- Endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise in East, South and South-East Asia due to projected changes in the hydrological cycle.

※ Figures in square brackets indicate the 90-percent confidence intervals for the best estimates. The probability that a given value is greater than or smaller than the specified interval is 5 percent. A confidence interval is not necessarily symmetrical about the corresponding best estimate.

2.2 Projecting Precipitation

2.2.1 Setting Meteorological External Forces

The precipitation used to assess risks and develop adaptation measures should be appropriately set as described in 2.2.2 to 2.2.5. An appropriate scenario should be selected, taking into consideration the uncertainty at each step, from a number of warming scenarios based on projected future changes in socio-economic conditions. Under the scenario, precipitation should be determined appropriately as a range of values from the projection results obtained from a climate change model such as a global climate model (GCM) by performing downscaling and analyzing precipitation statistics.

2.2.2 Setting Global Warming Scenarios

It is important that the global warming scenarios are developed properly based on projected future precipitation patterns. Note that global warming scenarios will change depending on global efforts to reduce greenhouse gas emissions.

Near-future projection results (after 20-30 years) may not vary greatly according to the scenario, so it is possible to reduce the number of scenarios to be considered. However, it is desirable to consider as many scenarios as possible, because long-term projection results will differ according to different scenarios.

The Fourth Assessment Report of IPCC takes future economic changes into account and uses the following scenarios for assessment:

A1: Rapid economic growth
A1F1: Technological emphasis on fossil energy sources
A1T: Technological emphasis on non-fossil energy sources
A1B: Technological emphasis on a balance across all sources
A2: Heterogeneous world
B1: Convergent world
B2: Intermediate population growth, local solutions

These scenarios describe possible future socio-economic levels in terms of population, economic activities, technological development and energy supply. Based on the scenarios, amounts of CO2 emissions, temperature rise, etc. are quantitatively projected. Note that these projections include uncertainty.

However, there is not sufficient information about climate changes, including temperature rise and rainfall, for all scenarios at present. Three types of scenarios, i.e., A1B, A2, and B2 have been used predominantly for developing global warming projection since other scenarios are more time-consuming and more expensive to develop. Furthermore, A1B is widely used for projecting global warming impacts and developing adaptation measures.

【Reference】Scenarios assumed in the IPCC Fifth Assessment Report

A new set of scenarios have been developed for the IPCC Fifth Assessment Report in place of the SRES (Special Report on Emission Scenarios) scenarios, which were used for IPCC's third and fourth assessment reports. In the conventional scenario development process, emission and socio-economic scenarios, climate scenarios, and impact scenarios were developed sequentially. In the new method adopted for the fifth assessment report, scenarios have been developed jointly and concurrently. As the first step, Representative Concentration Pathway (RCP) scenarios concerning the intensity of the greenhouse effect were developed. RCPs assume four radiative forcing levels in 2100, namely, 8.5 W/㎡ , 6 W/㎡ , 4.5 W/㎡ and 2.6 W/㎡ . On the basis of these assumptions, projections for emission and socio-economic scenarios and climate scenarios are made. Under the RCP scenarios, coupled atmosphere–ocean models and earth system models including the carbon and aerosol cycles are used for global warming projection (climate scenario projection), and detailed land use scenarios are made available. Various socio-economic scenarios can be developed from a single RPC radiative force level.

Table2-1 RCP scenarios used in AR5

Name	Radiative forcing level in 2100	Type of scenario
RCP8.5	8.5 W/㎡ in 2100	Rising
RCP6	Stabilized at 6.0 W/㎡ after 2100	Stabilization without overshoot
RCP4.5	Stabilized at 4.5 W/㎡ after 2100	
RCP2.6	Peak at 2.6 W/㎡ before 2100 and then decline	Peak and decline

References:
http://www.iiasa.ac.at/web-apps/tnt/RcpDb/dsd?Action=htmlpage&page=welcome
http://www.aimes.ucar.edu/docs/IPCC.meetingreport.final.pdf

2.2.3 Selecting the Climate Model

Future rainfall projections are needed in order to discuss adaptation measures. The Global Climate Model (GCM) is typically used for projection. GCM includes the following three models:

- Atmospheric General Circulation Model: AGCM
- Ocean General Circulation Model: OGCM
- Atmospheric Ocean General Circulation Model: AOGCM

Simulations of climate change projections are typically based on AOGCM because oceans considerably impact climate changes.

Simulated values and projected values of temperature rise and precipitation output using the GCM spatially represent large circulation scales (100-400km). As it is difficult to directly reproduce convectional rain, which is a phenomenon of several to tens of kilometers, on this scale, calculation should be performed using parameterization that estimates the structures of small-scale phenomena from large-scale phenomena. The parameterization method macroscopically describes the effects of turbulence and cumulus convection, but causes differences in replicating physical processes relating to cloud and water. Therefore, the results of climate change simulation may differ among models in each area. Also, it is necessary to consider that uncertainty is included. Some models are not capable of reproducing weather phenomena peculiar to a region of interest such as a Bai-u front. Therefore, when projecting a change in the tendency of a heavy storm causing flooding, it is important to use projection calculation results obtained from multiple GCMs capable of accurately reproducing region-specific precipitation phenomena.

2.2.4 Downscaling

In order to overcome global climate model (GCM) related problems mentioned in Section 2.2.3, particularly problems attributable to a large spatial scale, it is necessary to reproduce and project rainfall distribution at the scale of river basins on the basis of GCM projections. This task is called "downscaling." Methods of downscaling are classified roughly into two types, namely, statistical downscaling and dynamic downscaling.

Statistical downscaling and dynamic downscaling have respective advantages and disadvantages. Decisions as to which method to use, therefore, should be made after considering all relevant factors such as the purpose of study, the hydrological quantities of interest, and the time and funds available for study.

It is important to determine the spatio-temporal resolution for the downscaling of rainfall distribution appropriately in view of such factors as the characteristics of the river basin of interest, the accuracy of previously conducted runoff analyses, and the risks to be identified. In river runoff analysis, it is common practice to perform calculation by using rainfall data at several kilometer to several tens of kilometer mesh resolution so as to meet the accuracy and reproducibility requirements.

A) Statistical Downscaling

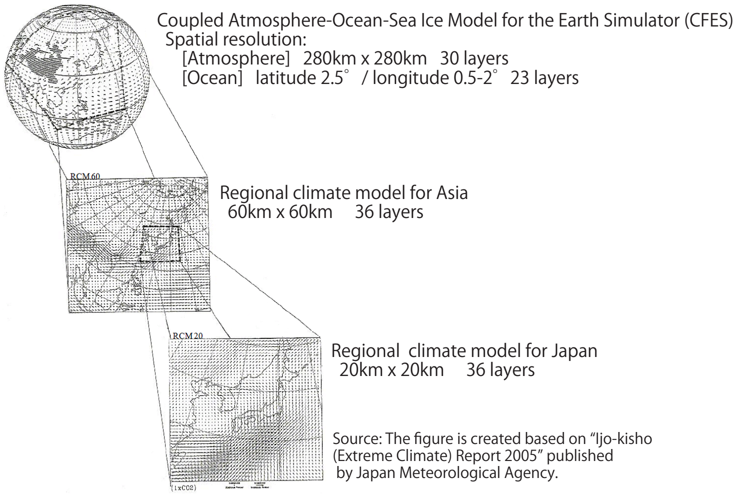
Statistical downscaling is a method that links actual meteorological/hydrological measurement values from the past to the present and GCM’s meteorological/hydrological calculation values through statistical methods (e.g. multiple classification analysis), and assumes that the link is applicable into the future. One method is to use the relationship between the past pressure pattern and the target amount and another method is to construct relational expressions by multiple regression analysis about relationships between multiple meteorological elements and the target amount. As described later, statistical downscaling is a method that can consider most of the generally released calculation results of GCM.

B) Dynamic Downscaling

Dynamic downscaling is a physical modeling method that downscales by recalculating target basin areas by RCM based on an equation with dynamic meteorology by setting GCM's output as a boundary condition. When calculating precipitation in tropical regions and monsoon regions, it is advisable to use a nonhydrostatic equilibrium RCM capable of expressing cumulus convection.

Regional Climate Models

	GC$\text{m}^2$0 (General Circulation Model)	RC$\text{m}^2$0 (Regional Climate Model)
Areas to be Calculated	Entire globe	Japan and surrounding areas
Horizontal Resolution	About 20 km Number of meshes 1920 x 9960	About 20 km Number of meshes 129 x 129
Number of Vertical Layers	60 layers	36 layers
Lateral Boundary Conditions	N/A, as this is a global scale mode.	Climate model for Asia



Source: The figure is created based on "Ijo-kisho (Extreme Climate) Report 2005" published by Japan Meteorological Agency.

Figure2-1 Concept of dynamic downscaling

Simulation modeling enables downscaled projections at the regional level.

C) Advantages and disadvantages

Bias correction

When there is big difference between recalculation results and observation values by downscaling, statistical correction and adjustment, which is called “bias correction,” is necessary.

Specifically, a correction formula empirically prepared in advance based on the present observation data is applicable. If the spatiotemporal scale of statistical downscaling is the same as that of observation values obtained in rivers and basins, statistical downscaling can identify bias correction. On the other hand dynamic downscaling emphasizing consistencies with dynamic meteorology is not exclusively sufficient for ensuring consistency with observation values , so the need for bias correction should be separately considered.

Statistical downscaling

＜ Advantages ＞

1) In principle, a relationship with actual measured values is quantitatively and directly optimized and identified, and the downscaling itself is expected to produce effects of bias correction and results which improve uncertainties.
2) Compared to dynamic downscaling, statistical downscaling quickly and effectively obtains target results, and requires less time and cost.
3) The demand for GCM’s calculation values necessary for downscaling is small, so most of the generally released calculation results of GCM can be selected, and it is easy to obtain the original data.

＜ Issues ＞

1) There are uncertainties and technological issues associated with the assumption that an empirical (statistical) rational expression obtained from verification results at present is applicable in the future.
2) The observation density of actual measured values of hydrological values is fundamental for downscaling, and it is generally difficult to freely and flexibly extract hydrological values with smaller spatiotemporal scale than observation data. Research is underway on methods for estimating hourly hydrological quantities by statistical processing in areas where only daily observation data are available. The use of these methods should be considered when necessary in view of the accuracy of downscaling.

Dynamic downscaling

< Advantages >

1) Dynamic downscaling is based on an equation with dynamic meteorology, and the relational expression used in downscaling is likely to be applicable in the future.
2) The physical amounts of various spatiotempral scales can be freely and directly extracted from calculation results.

< Issues >

1) Compared to statistical downscaling, there are many cases which require bias correction.
2) There are relatively few cases of GCM's calculation recording and providing sufficient calculation results for determining initial and boundary conditions needed for nesting calculations for dynamic downscaling, and the calculation load is very large, so the data is unlikely to be used at present. However, the Coupled Model Intercomparison Project Phase 5 (CMIP5) to provide calculation results allowing dynamic downscaling is currently in progress and sufficient calculation results for dynamic downscaling will be released in the autumn of 2010.

2.2.5 Projection and Statistical Analysis of Precipitation

It is common practice to calculate the precipitation corresponding to a particular probability of exceedance by conducting a statistical analysis of precipitation based on the precipitation data obtained as described in Section 2.2.4.

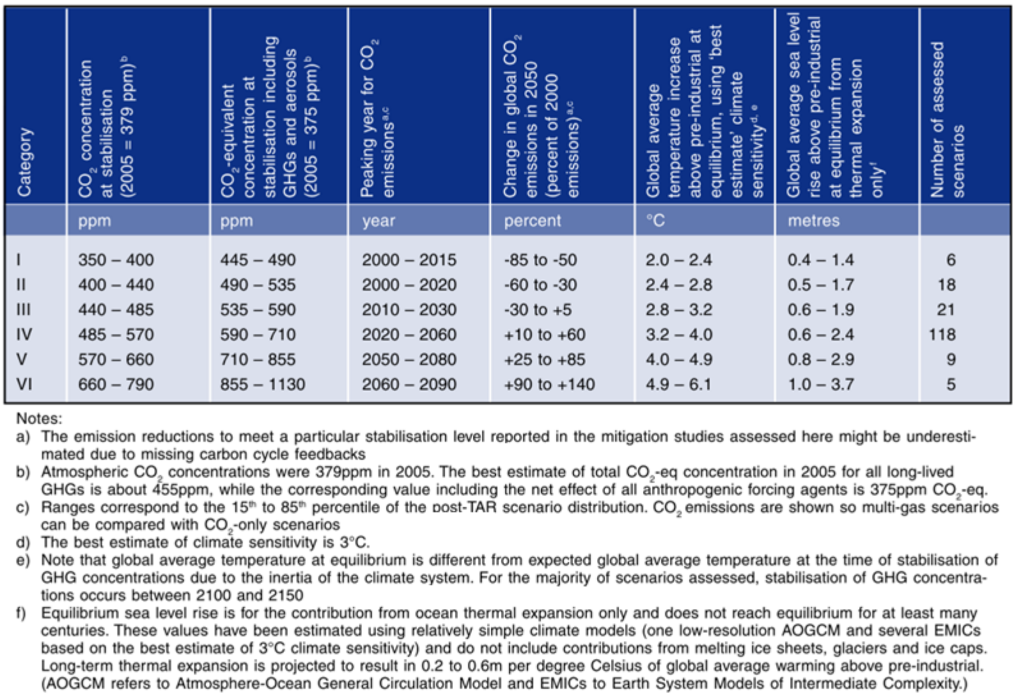
As mentioned in Section 1.3, the uncertainty due to the differences between global climate models is thought to be greater than the uncertainty due to the differences between downscaling methods. It is thought, therefore, that future estimates of the spatio-temporal distribution, including the range of uncertainty, of precipitation necessary for runoff analysis can be obtained by performing the downscaling calculation mentioned in Section 2.2.4. The method of determining the range of uncertainty by performing calculation under different sets of input conditions (boundary conditions in this case) is called "ensemble projection." It may be good practice to use multiple downscaling methods so as to allow for the uncertainty inherent in downscaling.

2.3 Projecting Sea Level Rise

Projections of sea level rise are performed based on potential climate changes. When understanding risks and developing adaptation measures, the projection results of sea level rise should be used as the boundary conditions of estuaries for flood propagation calculations or analysis in river channels.

As described in 2.2.2, there are many scenarios for global warming, and sea level rise is projected based on these scenarios, in addition to using regional climate models.

Projections of sea level rise may include uncertainties in developing scenarios and calculation models. This should be recognized and projection results should be appropriately selected so that they can be used for assessment and examination.



Category	CO_2 concentration at stabilisation (2005 = 379 ppm)[b]	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005 = 375 ppm)[b]	Peaking year for CO_2 emissions[a,c]	Change in global CO_2 emissions in 2050 (percent of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d, e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

Notes:

a) The emission reductions to meet a particular stabilisation level reported in the mitigation studies assessed here might be underestimated due to missing carbon cycle feedbacks

b) Atmospheric CO_2 concentrations were 379ppm in 2005. The best estimate of total CO_2-eq concentration in 2005 for all long-lived GHGs is about 455ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375ppm CO_2-eq.

c) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios

d) The best estimate of climate sensitivity is 3°C.

e) Note that global average temperature at equilibrium is different from expected global average temperature at the time of stabilisation of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150

f) Equilibrium sea level rise is for the contribution from ocean thermal expansion only and does not reach equilibrium for at least many centuries. These values have been estimated using relatively simple climate models (one low-resolution AOGCM and several EMICs based on the best estimate of 3°C climate sensitivity) and do not include contributions from melting ice sheets, glaciers and ice caps. Long-term thermal expansion is projected to result in 0.2 to 0.6m per degree Celsius of global average warming above pre-industrial. (AOGCM refers to Atmosphere-Ocean General Circulation Model and EMICs to Earth System Models of Intermediate Complexity.)

（Source:　AR4（Fourth Assessment Report）　SYR（Synthesis Report）　SPM（Summary for Policymakers））

Figure2-2　Temperature rise and sea level rise projections

Characteristics of post-TAR （Third Assessment Report）stabilisation scenarios and resulting long-term equilibrium global average temperature and the sea level rise component from thermal expansion only.

2.4 Collecting and Sorting Basin and Other Data

Data on catchment areas, rivers, and floodplains must be collected and sorted in order to understand risks and develop adaptation measures.

Catchment data includes altitude, land use, vegetation, and water retention capacity, which are used to analyze runoff and other hydrological values. River data includes longitudinal profiles, cross-sections, flood retarding areas, levees, river facilities, vegetation cover in river channels, riverbed materials and sediment transport, which are used to understand channel flow capacity and to calculate flood propagation in river channels, etc. Floodplain data includes channels, continuous embankment structures, property, and population for inundation analysis, etc. in addition to basin data. The available data should be collected and sorted. Also, when there are plans or projections regarding population or land use, those should be collected and classified.

Catchment data and floodplain data should be organized as mesh data to integrate each calculation. River data should be organized according to the method of calculating flooding in river channels.

In addition to the above-mentioned data, hydrological and hydraulic values relating to river flow and flooding such as discharge, water level, flooding depth, etc. are collected and sorted. These data are necessary to verify hydraulic and hydrological models and may compensate for the insufficiency of information about rivers and basins.

It is also desirable to use accurate data on basins, rivers and floodplain areas, but if it is difficult to collect accurate data, satellite-based data, such as global mapping provided by the International Steering Committee for Global Mapping (ISCGM), etc. should be used as necessary.

For collecting and sorting basin data, etc., it is important to control the accuracy while considering the balance of accuracy of the overall data. The accuracy of calculation results is decided by:

(1) Accuracy of input and boundary conditions,

(2) Accuracy of calculation models (constitutive equation),

(3) Accuracy of parameters used for the calculation. For example, if detailed and accurate data of (1) is collected and accurate data of (2) and (3) is not collected, then the accuracy of (1) in the calculation results is not ensured. Also, the accuracy of calculation results is required to meet:

(4) Accuracy necessary for understanding risks and developing adaptation measures.

Therefore, it is important to appropriately examine what kind of information and what level of accurate data should be collected or combined, depending on the characteristics of the target area.

2.5 Understanding Hazards, Vulnerabilities and Risks

2.5.1 Importance of Understanding Hazards, Vulnerabilities and Risks

It is important to assess the conditions of floodplains and the impacts of climate changes in the present and future to obtain basic information for considering the methods to avoid, reduce, transfer and retain risks on floodplains. and for developing adaptation measures.

Analyzing hazards, vulnerabilities, and risks as described in 2.5.3 contributes to understanding how hazards, vulnerabilities and risks change in each floodplain block in the present and the future and what adaptation measures should be implemented.

【Reference】“Hazard,” “Vulnerability,” “Risk” and “Resilience”

The terms of “Hazard,” “Vulnerability,” “Risk” and “Resilience” are used in many books or plans regarding impact assessments of natural disasters.

For instance, the UNISDR Terminology on Disaster Risk Reduction (2009) defines “hazard” as “a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.” “Vulnerability” is defined as “the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.” “Disaster Risk” is defined as “the potential disaster losses in lives, health status, livelihoods, property and services, which could occur to a particular community or a society over some specified future time period.” “Resilience” is defined as “the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.”

2.5.2 Setting Conditions for Understanding Hazards, Vulnerabilities, and Risks

In order to understand hazards, vulnerabilities, and risks, it is necessary to set appropriate conditions of external forces of precipitation, etc., the target year for assessment, socio-economic situations, and the development status of flood control facilities, and then to analyze the hazards, vulnerabilities, and risks.

First, external forces of precipitation, etc. are assessed with multiple precipitation scales exceeding the safety levels of current flood control measures to understand the impacts on various precipitation scales. Also, to understand the impact of changes in future projection values, multiple future precipitation projection values set under the present assessment are assessed. Furthermore, to understand the impact of changes at each phase of adaptation measures, the target year for adaptation measures described in 1.2.2 should be assessed, if necessary. In this case, socio-economic conditions should be set as land use, population and property distribution in each target year for the assessment and the condition of flood control facilities should be set assuming the development status of flood control facilities based on previous plans, etc.

2.5.3 Methods for Analyzing Hazards, Vulnerabilities and Risks

1) Overview

To analyze increasing flood risks, it is necessary to calculate the economic damage, human damage, damage to core facilities, and failure of central functions caused by river flooding.

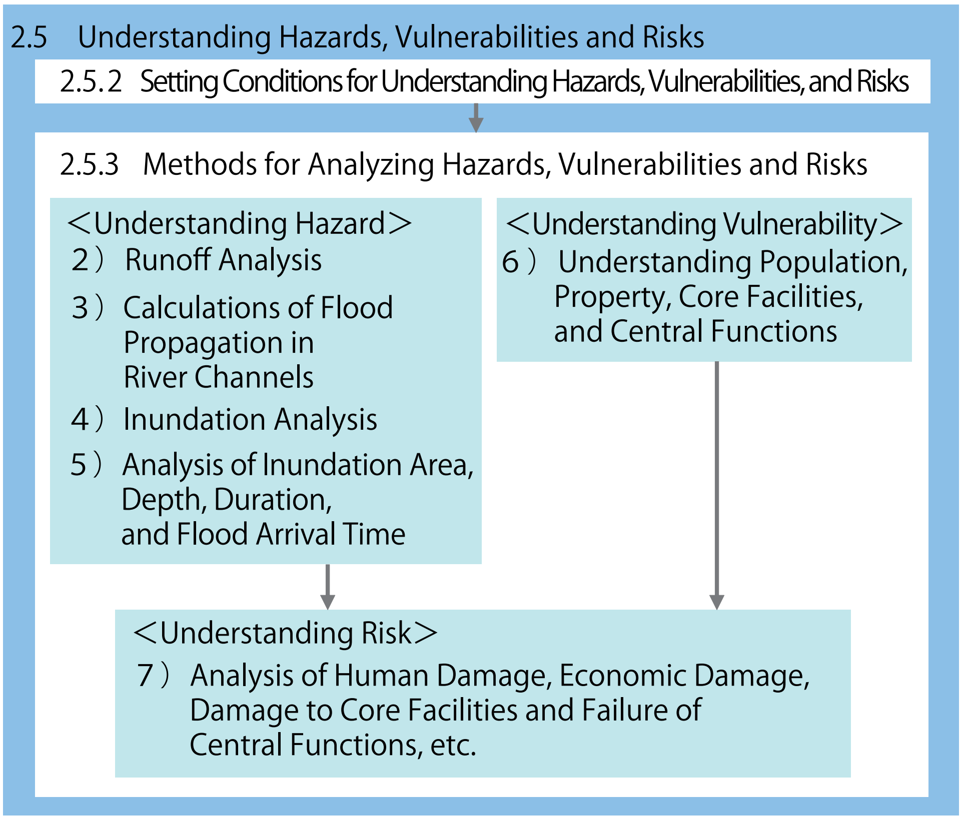
In estimating the impacts of economic damage, human damage, damage to core facilities, and failure of central functions caused by river flooding, a model of the process from rainfall, runoff, and up to flooding needs to be created. The model should then be used to understand the changing risks depending on climate changes, socio-economic circumstances, and the development conditions of flood control facilities.

Specifically, it is necessary to create (i) a runoff model where rainfall is converted to runoff through runoff analysis, (ii) a propagation model of the runoff hydrograph by calculating river flood propagation, (iii) an inundation phenomenon model from rivers to floodplain, (iv) a flood flow model through the floodplain and (v) a drainage model of the inland water. This series of models is then used to estimate inundation areas, inundation depth, duration of inundation, and temporal changes in inundation depth in floodplain corresponding to the precipitation. In order to understand the inundation areas, it is important to clarify the population in the floodplain, the height of inhabited buildings, property, core facilities, etc. Using the calculation results, human damage, economic damage, damage to core facilities, and failure of central functions are generally estimated.

It is money- and time-consuming to construct and run a river and basin model combining various element models with the aim of simulating complex physical phenomena. In order to raise the level and efficiency of hydraulic, hydrologic and other analyses, the National Institute for Land and Infrastructure Management has developed and released Common MP (Common Modeling Platform for water–material circulation analysis), which makes it possible to use any desired combination of element models.

If a sufficient amount of data is not available for analysis, one option is to use a simple alternative method such as using past flood data.

The flowchart below shows the process of risk identification in these guidelines.



【Reference】Common MP (Common Modeling Platform for water-material circulation analysis)

Common MP is a common software platform developed and released by a team led by the National Institute for Land and Infrastructure Management in order to raise the level and efficiency of analysis of various complex hydraulic and hydrologic phenomena (Ver. 1 released in March, 2010).

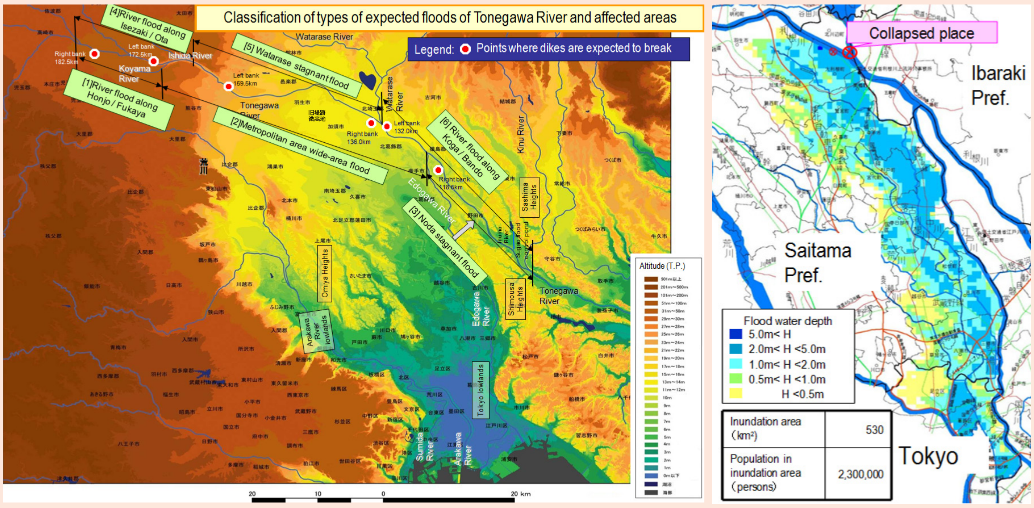
Common MP enables the user to construct and combine a desired combination of element models (analysis models) capable of performing different functions on the basis of the disclosed specifications. Common MP, therefore, makes it possible to apply existing element models such as the previously developed runoff, propagation and inundation phenomenon models to river basins with similar characteristics or to develop new element models suitable for application to particular river basins and combine them with existing models in order to perform analyses with higher accuracy. By making effective use of element models in this way, complex analyses can be performed efficiently.

（http://framework.nilim.go.jp/eng/index.html）

【Reference】Large-scale flood damage mitigation measures in Tokyo Metropolitan Area

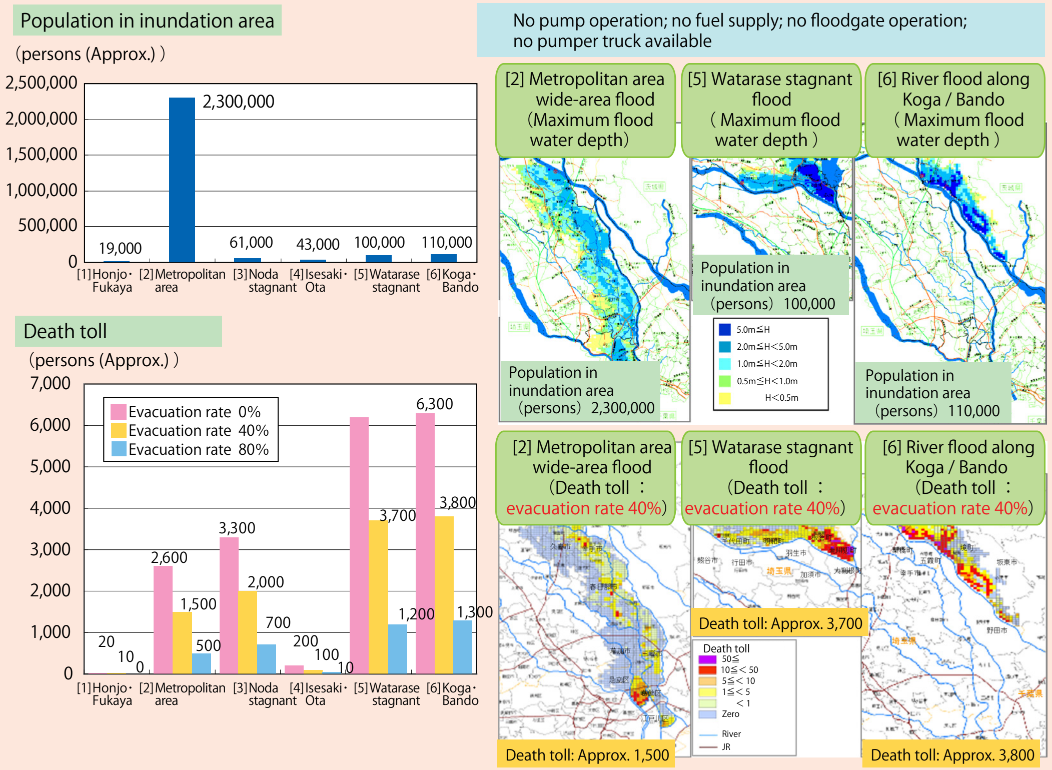
In 1947, Typhoon Kathleen caused a breach in one of the levees of the Tone River in Higashi Village (present-day Kazo City, formerly Otone Town) in Saitama Prefecture, inflicting extensive inundation damage in the Tokyo Metropolitan Area including part of Tokyo's 23-ward area. Through Japan's post-war economic growth, TMA in particular has built up a massive concentration of political and economic functions and the population has increased to about 43 million. If flooding occurs in the Tokyo Metropolitan Area because of a levee breach along a river such as the Tone River or the Ara River, the resulting human casualties, property damage and economic loss are likely to surpass those caused by Typhoon Kathleen. The time and cost required for rehabilitation/restoration will be unimaginably long and high. In view of the possibility of a major flood caused by overtopping of the Tone or Ara river levees or a storm surge in Tokyo Bay, therefore, there was a pressing need to decide on emergency measures, disaster prevention measures and restoration/rehabilitation measures to minimize damage in the event of a major flood.

Thus, the Expert Panel on Large-Scale Flood Disaster Countermeasures was established in the Central Disaster Prevention Council in June, 2006 to deliberate on such measures as the first expert panel focusing on large-scale flood disasters. On the basis of the latest knowledge, the expert panel conducted simulations of flooding in the event of a levee break along the Tone, Ara and other rivers or a massive storm surge in Tokyo Bay to gain better understanding of how flooding occurs. As the first attempt of its kind in Japan, the committee also analyzed various risks existing in the metropolitan area based on assumptions about human suffering including the number of deaths and the number of people left behind and other aspects of damage. The committee also deliberated on measures, particularly emergency response measures, to be taken in the event of a major flood in the metropolitan area, taking into consideration the study results mentioned above and past flood disasters. In April, 2010, the committee prepared a report on the results of these deliberations.



(Provided by the Cabinet Office)

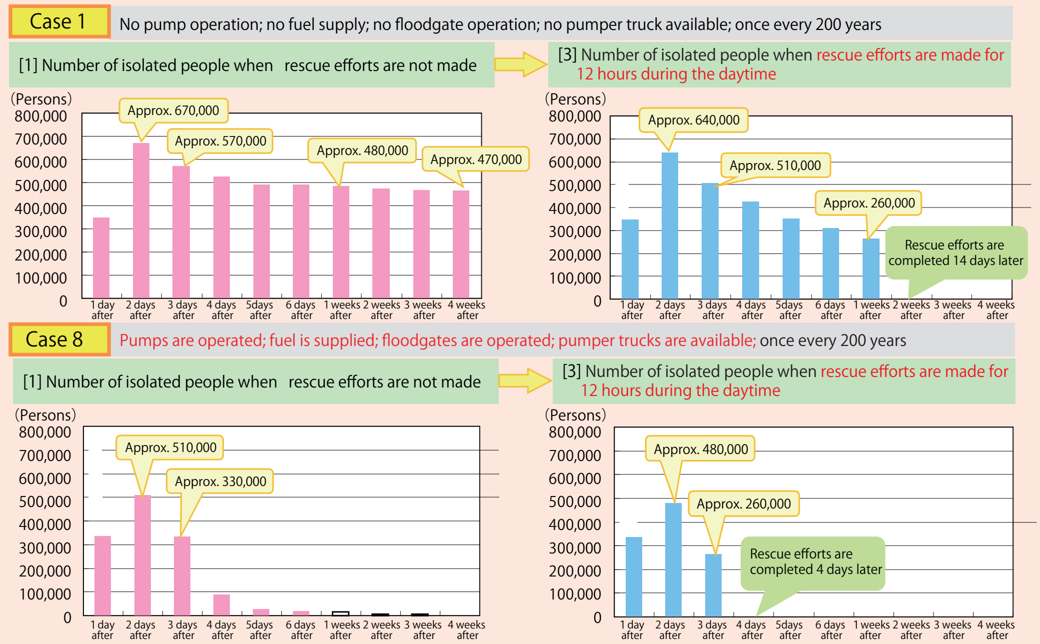
Figure2-3 Flooding simulation results
(study on large-scale flood damage mitigation in Tokyo metropolitan area)



(Provided by the Cabinet Office)

Figure2-4 Effects of drainage operations on death toll (study on large-scale flood damage mitigation in Tokyo metropolitan area)

The number of deaths resulting from levee breach induced flooding of the Tone River caused by a 200-year flood was studied. As a result, it has been found that the number of deaths in an area with a large inundation area and a large population is not necessarily large ([2] Metropolitan area wide-area flood), and that the number of deaths in an area with a small inundation area and a small population may be large if the flood water stays long ([5] Watarase stagnant flood, [6] River flood along Koga/Bando). These results indicate that the number of deaths is greatly affected by the form of flooding.

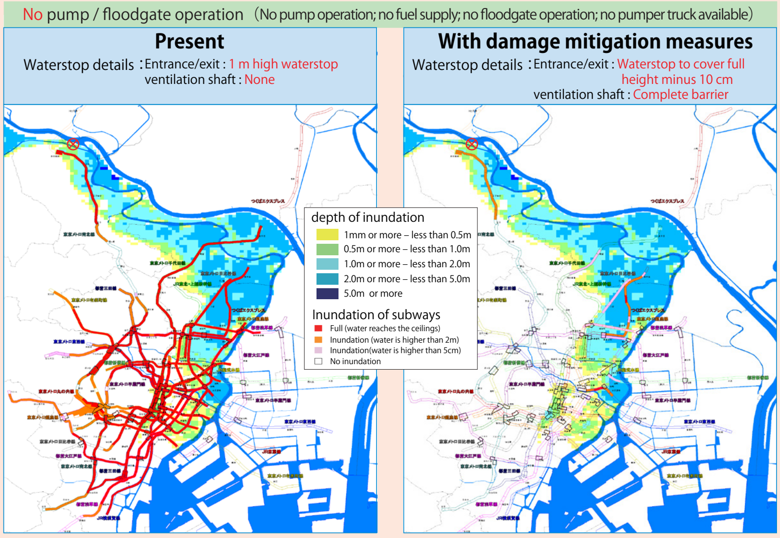


(Provided by the Cabinet Office)

Figure2-5　Number of people left behind
(study on large-scale flood damage mitigation in Tokyo metropolitan area)

The number of people left behind resulting from levee breach induced flooding of the Tone River caused by a 200-year flood was studied. In the event of large-scale flooding, pump stations may be rendered inoperable by inundation. Even if pump stations are not inundated, the inundation of adjacent areas may hamper refueling, or it may not be possible to operate pump stations, floodgates, etc., because of the need to ensure safety of operation personnel. When considering the number of people left behind, it is important to make appropriate assumptions about the operating status of drainage facilities.

The study on the number of people left behind has revealed that if drainage facilities are rendered inoperable and rescue activities are not carried out by the police, fire departments or the Self-Defense Forces, several hundred thousand people will be isolated for a period of several weeks. The study has revealed that in cases where rescue activities are carried out, rescue will be completed in 14 days after a levee breach if drainage facilities are rendered inoperable or in four days if drainage facilities that have not been flooded can be operated.



(Provided by the Cabinet Office)

Figure2-6 Expansion of inundation through subway and other tunnels (study on large-scale flood damage mitigation in Tokyo metropolitan area)

An analysis of inundation damage caused by levee breach induced flooding of the Ara River taking into consideration the networks of subway and other tunnels has revealed that underground malls and building basements may be inundated through tunnels even when the ground surface is not inundated, and that subway and other tunnels may be inundated earlier than the ground surface.

2) Runoff Analysis

Runoff analysis is performed using runoff calculation models where the amount of rainfall is converted to runoff.

A rainfall event may turn into runoff under spatial and temporal combinations of basin topography, geology, soil, climate, and land use, which change with various causes. In runoff calculation models, complicated runoff phenomena are simply modeled, or simple function formulae are used to describe the phenomena, and thus the runoff volume is determined.

If it is difficult to provide sufficient precipitation and runoff data required for identifying the model, from actual measurements using only ground-based observation data, an alternative method can be applied. As described in 2.1, data obtained from satellite-based rainfall observations can be used for rainfall data, to compensate for insufficient data. It is also possible to assume runoff data by using precipitation data by a first approximation of distribution parameters showing elements in hydrological processes from mapping information of geography and land use of basins. IFAS released by ICHARM includes a tool for easily performing these in the software. This tool can help to identify a runoff model of a river where there are insufficient datasets.

【Reference】IFAS（Integrated Flood Analysis System）

IFAS distributed by ICHARM is a flood analysis system that utilizes satellite precipitation data and a geographic information system. IFAS makes it possible to perform runoff analyses and flooding analyses of areas where there are few or no ground-based observation stations and precipitation and other basic data are lacking. IFAS, therefore, is thought to be particularly useful in developing countries that do not have adequate ground-based hydrologic observation systems.

IFAS is capable of entering not only ground-based precipitation data but also satellite-based precipitation data, which tend to become underestimates in the event of a heavy rain, after making data correction by using rain area movement data. IFAS also has two types of distributed constant type runoff analysis models so that a runoff analysis model can be constructed in any part of the world. IFAS is designed to facilitate river basin extraction, channel network generation and parameter setting from universally available GIS data (e.g. USGS-GTOPO30, USGS-GLCC). An easy-to-understand interface is another feature of IFAS.

(IFAS Website: http://www.icharm.pwri.go.jp/research/ifas/index.html)

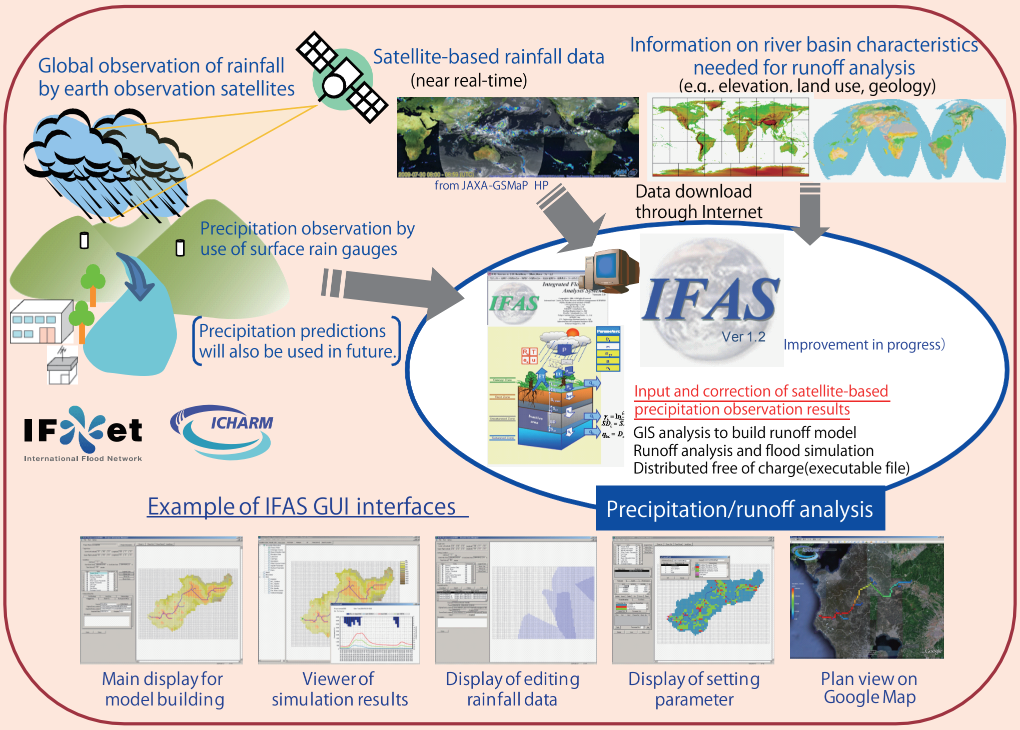


Figure2-7 Discharge analysis technology using satellite data

3) Calculations of Flood Propagation in River Channels

Propagation calculations in river channels are used to determine the state of flood flows under the boundary conditions related to channel shape, channel conditions (such as riverbed materials, ground cover and information about river structures), discharge volume, and water level.

The IFAS includes a tool to integrally analyze the calculations from the runoff calculations to the flood propagation calculations in a river channel.

4) Inundation Analysis

Based on the flood flow data calculated by flood propagation calculation, the flood conditions in the floodplain assuming overflow from a dike and/or dike break in the target river during times of flooding are calculated.

For a flood flowing down a narrow area along a river channel, generally a one-dimensional model is used, whereas a two-dimensional model is used for a planar flood.

5) Analysis of Inundation Area, Depth, Duration and Flood Arrival Time

Hazardous conditions in the floodplain are analyzed by inundation analysis. Specifically, inundation range, area, maximum depth, duration and flood arrival time are generally analyzed based on calculation results by inundation analysis.

6) Understanding Population, Property, Core Facilities, and Central Functions

The situation of the inundation area should be understood. Specifically, the distribution of population and vulnerable people; land use in urban areas and on farmland; accumulation of property; number of stories of buildings; core facilities such as stations, hospitals, electric power substations, fire stations, temporary shelters; and highways and public offices that could lead to the breakdown of central functions of politics, public administration and finance are generally identified by using floodplain data collected and sorted in 2.4.

7) Analysis of Human Damage, Economic Damage, Damage to Core Facilities, and Failure of Central Functions, etc.

It is necessary to identify as clearly as possible, the possibility of flooding and what/how could be damaged by inundation before analyzing them. It is very important to use various indices for the analysis, not a single index. It is also important to analyze the effects of inundation; and the area, population and facilities affected by inundation from diverse points of view. Specifically, human damage, economic damage, and damage to core facilities should be calculated in view of the inundation in the floodplain. Based on the estimated extent of damage to central functions, various damages caused by flooding are usually analyzed. When performing such analyses, it is important to concretely estimate and understand not only direct effects but also indirect effects, such as the effects of inundation damage in the floodplain and the interruption of the movement of people and goods due to inundation on the social and economic activities in and outside the floodplain, and the spreading of epidemics and the occurrence of communicable diseases due to the deterioration of sanitary conditions. It is important to comprehensively understand the risks based on regional characteristics, present situation, and future trends by effectively using these risk analysis results.

Table2-2　Types of inundation damage

Category				Description of damage
Direct damage	Property damage	General property damage	Housing	Inundation damage to buildings for residential or business use
			Household appliances	Inundation damage to furniture, automobiles, etc.
			Depreciable business property	Inundation damage to depreciable fixed business property excluding land and buildings
			Business inventory property	Inundation damage to business inventory
			Depreciable agricultural/fisheries property	Inundation damage to depreciable fixed agricultural/fisheries property related to agricultural/fisheries production excluding land and buildings
			Agricultural/fisheries inventory property	Inundation damage to agricultural/fisheries inventory
		Agricultural product damage		Inundation damage to agricultural products
		Damage to public civil engineering facilities, etc.		Inundation damage to public civil engineering facilities, public works facilities, agricultural land or agricultural facilities
	Human suffering			Injury or loss of life
Indirect damage	Operational damage	Business interruption damage	Household	Damage due to hindrance to normal household activities, leisure activities, etc., of inundation-affected households
			Business	Interruption of production activities (decrease in production output) of inundation-affected businesses
			Public service	Discontinuance or interruption of inundation-affected public services
	After-the-fact damage	Cost of emergency measures	Household	Damage in the form of new cost to inundation-affected households for response activities such as cleanup and for the purchase of substitutes such as drinking water
			Business	Damage similar to that suffered by households
			State/local government	Damage similar to that suffered by households, the interest on emergency loans provided by municipal governments or other organizations, condolence payments, etc.
		Consequential damage due to traffic interruption	Roads, railways, airports, ports, etc.	Consequential damage in the affected and adjacent areas due to t interruption involving roads, railways, etc.
		Consequential damage due to severing of lifelines	Electricity, water supply, gas, telecommunications, etc.	Consequential damage in the affected and adjacent areas due to t interruption of the supply of electricity, gas, water, etc.
		Consequential damage due to business interruption		Consequential damage in the affected and adjacent areas due to decreases in production by nearby businesses because of shortage of intermediate products, the interruption of hospital and other pu services, etc.
	Mental damage	Damage due to property damage		Mental impact due to property damage
		Damage due to operational damage		Mental impact due to operational damage
		Damage due to human suffering		Mental impact due to human suffering
		Damage due to after-the-fact damage		Mental impact due to cleanup labor, etc.
		Damage due to consequential damage		Mental impact due to consequential damage
	Risk premium			Concern about vulnerability

Flood Control Economy Survey Manual (prepared by MLIT) describing methods for calculating the benefits of flood control projects introduces the types of inundation damage listed in the table above.

3. Developing Adaptation Measures

3.1 Setting Goals for Flood Management Measures

As mentioned in Section 1.2.2, for example, the results of a 100-year projection differ considerably depending upon the warming scenario used. The treatment of uncertainty, therefore, requires careful consideration. It has been found, however, that global average temperature projections over a period of about 20 to 30 years do not vary so widely. It is thought, therefore, at least at present, that it is good practice to estimate changes over a period of about 20 to 30 years while also considering longer-term changes, so that effective and specific adaptation measures can be taken to address short-term impacts. In developing adaptation measures, it is necessary to define the concept of flood control measures and to set both short-term goals and long-term goals in view of the degrees of uncertainty involved in projections over different periods of time.

The goals must be made specific, by considering how to avoid, mitigate, transfer or take risks identified in 2.5, as well as past disaster damage, natural and social characteristics of basins, future national visions (development goals), and limitations on investment capability (financial strength). It is important to set goals in combination with multiple goals as required.

When drawing up specific goals, studies on “where and by how much the loss of life, economic damage, and social impacts should be decreased” must be done while considering fairness and emphasizing important factors, etc. The positive effects of flooding on agriculture and fisheries should be considered as well. Also, considering the land use of basins and floodplains, expansion and vertical growth of urban areas, etc., and areas where concentration of population and industries should be promoted or limited in the long run should be identified as required and reflected in the studies. According to those conditions, general goals should be set such as “Minimize victims,” “Avoid paralysis of capital city functions,” “Avoid catastrophic damage” and “Avoid flood damage in urban areas in the event of a 30-year flood” and “Control the frequency of flooding once in XX years.” Based on these goals, after developing and setting adaptation measures by the method described in 3.2, it is important to clearly present and specify goals in terms of time, cost, etc.

3.2 Optimal Combination of Adaptation Measures

3.2.1 Options for Adaptation Measures

It is important to fully understand the characteristics, range of application, and limit of each adaptation option when developing climate change adaptations. A measure or combination of several options appropriate for each river basin is affected by the climate (hydrological and hydraulic) characteristics of the basin and socio-eco nomic situation. Measures may differ under different conditions and countries. Because financial and legal systems, administrative organizations, infrastructure conditions and the level of public awareness of disasters differ among countries, it is necessary to carefully evaluate the effectiveness of adaptation measures, taking such differences into consideration .

The major options of adaptation measures are outlined below.

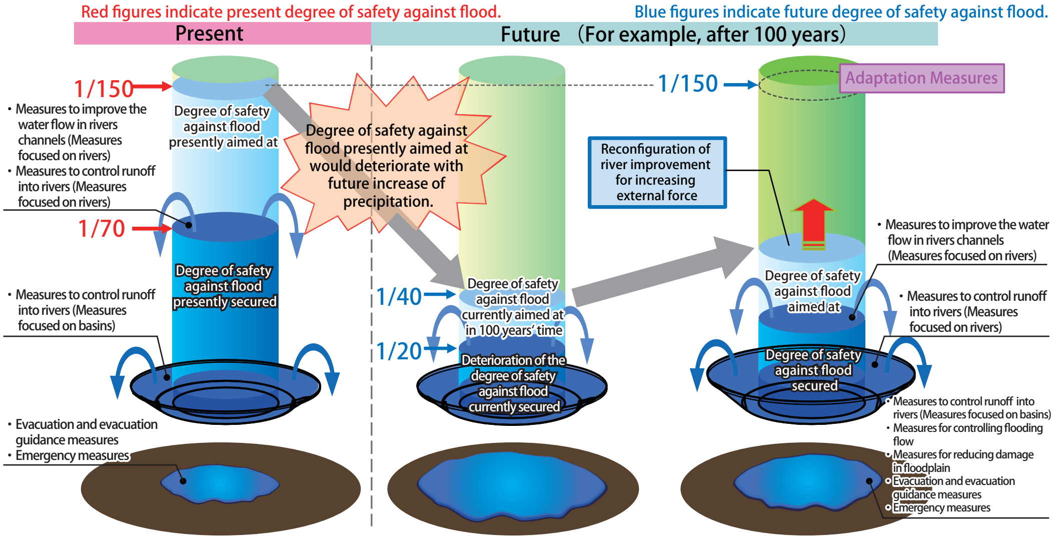


Figure3-1 Implementation of multilayered adaptation measures consisting of an appropriate combination of adaptation measures

In order to cope with growing external forces because of climate change, it is necessary to implement multilayered adaptation measures consisting of a combination of adaptation measures.

A. Measures for reducing risks of inundation (excavation of river channels, levee setting back, embankment, dam, flood control facilities, etc.)

The measures for reducing inundation risks are classified broadly into measures for improving river channels such as expansion of river channels, excavation of river bed, and embankment and measures for controlling flooding such as dam or flood control facilities. For both measures, the impacts on communities and the natural environment should be considered.

・Measures to improve the water flow in river channels (Measures focused on rivers)

Measures are taken such as improving the water flow in river channels. Such measures prevent flooding of residential areas, etc. and can greatly improve the safety of inundation areas. Major measures and their characteristics are as follows:

Excavation of river channels: If excessive excavation is carried out, the flow force for carrying sediment might weaken and sediment might accumulate again;

Levee setting back and embankment: If a continuous levee is built, it may take time and cost for land acquisition, bridge reconstruction, etc.;

Discharge channels and cut-off channels: There is a method that combines the development of discharge channels and cut-off channels in addition to a method that improves existing river channels, but it is necessary to coordinate with persons involved in the land acquisition and new stakeholders of channel development;

Floodgate: If necessary, a floodgate is placed at the point where the two rivers meet; and

Inland water drainage: If an embankment is improved, a measure for inland water drainage is necessary.

When implementing river management measures such as riverbankerosion control measures, it is necessary to decide on methodsin view of country-specific factors such as social and economicconditions and the natural environment.

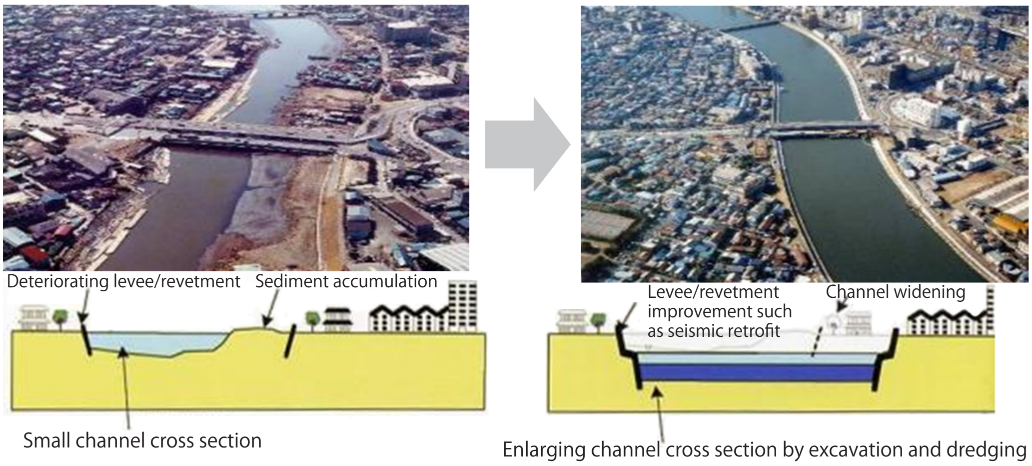
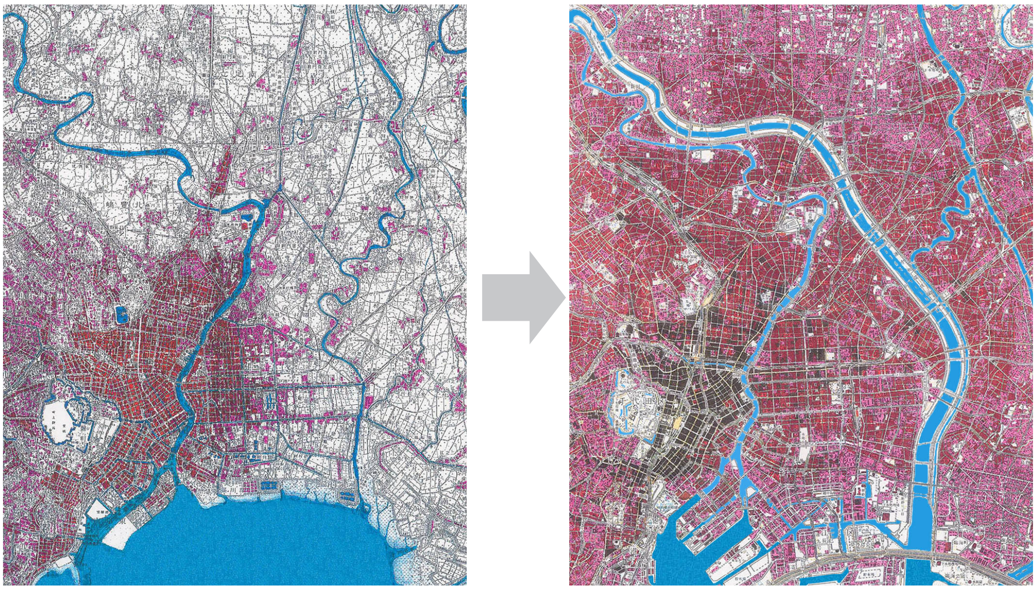


Figure3-2　Deteriorating levee/revetment

Channel excavation to increase water depth and levee setback to increase the discharge capacity of the channel by increasing channel width

Figure3-3　Embankment

Levee construction to increase the discharge capacity of the channel and reduce overtopping risk



The Old Ara River before the construction of the floodway (The present-day Sumida River)

The present-day Ara River

Figure3-4　Floodway

The construction of a new channel to increase the flood discharge capacity and reduce overtopping risk

For the Ara River running through Tokyo, a 22-kilometer-long, 500-meter-wide floodway was constructed following the great flood of 1910.

【Reference】Example of erosion control works selected according to country-specific conditions (fascine mattress method)

The fascine mattress method is one of Japan's traditional erosion control methods. In this method, bundles of twigs cut from broad-leaf trees are assembled into lattices. Then, the lattices are stuffed with stones and sunk to the bottom of the river. Light in weight, strong and flexible, fascines can be easily bent to fit the undulating surface of the riverbed and are effective in dissipating the energy of flowing water and preventing uneven bed scouring by water. Since the spaces in fascine mattresses vary in shape and flow velocity in fascine mattresses varies widely, habitats for various species of aquatic life such as small fishes and benthos are created.

Because this technique is inexpensive and utilizes locally available resources, it has been transferred to Laos. Today, the fascine mattress method is widely used as a bank erosion control method for the Mekong River.

Figure3-5　(fascine mattress method)

- Measures to control runoff into rivers (Measures focused on rivers)

The measures for controlling flooding to rivers reduce the peak flow and damage by storing flooding water in reservoirs, etc. The major measures and their characteristics are as follows:

Dam: The safety of the floodplain can be greatly improved depending on the location and scale of facilities, but it is necessary to (i) compensate for submerged land, etc., (ii) coordinate with those involved and (iii) prevent water and sediment from flowing downstream;

Flood control facilities: The safety of the floodplain can be greatly improved depending on the location and scale of facilities. Compensation for submerged areas and adjustment with persons involved are necessary; and

Effective utilization of existing facilities: The flood control capability can be enhanced by (i) enlarging existing dams, (ii) improving discharge facilities, (iii) purchasing service water capacity or (iv) improving short-term precipitation prediction technology and reservoir operation technology. These measures, however, may require such efforts as coordinating with stakeholders and paying compensation for the impacts of those measures.

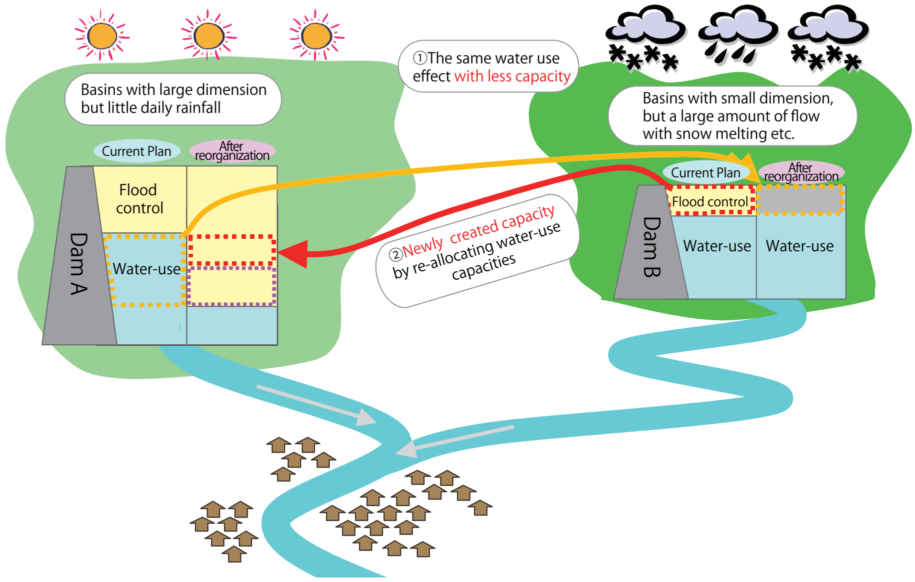


Figure3-6　Utilization of exciting structures　（Re-organization of dams ）

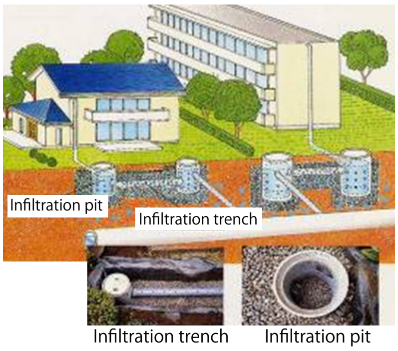
- Measures to control runoff into rivers (Measures focused on basins)

Measures to reduce runoff into rivers include the use of stormwater storage and infiltration facilities located in river basins.

Storage and infiltration facilities: Facilities provided for the storage or infiltration of stormwater in order to maintain the retention and detention capacity of urban areas. These facilities include storage facilities such as storage pipes, on-site storage facilities, storage facilities between housing complex buildings, playgrounds and open spaces, and infiltration facilities such as infiltration pits, infiltration wells and permeable pavements. These facilities may effectively reduce flood peak discharge in relatively small urbanized river basins.

Rainwater storage and infiltration facility

Rainwater storage at school ground



Infiltration pit and trench

Permeable pavement

Rainwater storage at residential area

Figure3-7 Measures to reduce runoff into rivers (measures focused on basins)

B. Measures for controlling flooding flow (e.g., secondary levees, open levees, ring levees)

These include measures to control flooding flow and enhance the safety of other areas in the floodplain (secondary levees), measures to return flooding flow to rivers and dissipate flooding flow (open levees) and measures to enhance the safety of residential land areas, etc., by surrounding residential land areas, etc. in floodplains. These measures require coordination with the people concerned with the areas where flooding is permitted.

Riparian forests (flood barrier forests) are effective in dissipating the energy of flood water, preventing levee breaches and mitigating flood damage.

(Secondary levees)

A continuous land-side embankment is constructed as a secondary levee to control flood flows and mitigate damage in the event of overtopping.

(Open levees)

River embankments are intentionally made discontinuous so that downstream flooding can be controlled by temporarily detain flood flows.

(Ring levees and raised house foundations)

Flood flows are controlled by constructing levees around houses or raising house foundations when, for example, houses to be protected would be moved if ordinary continuous levees are built.

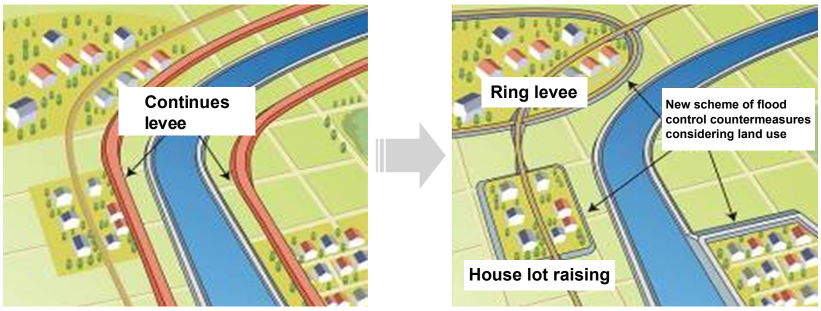
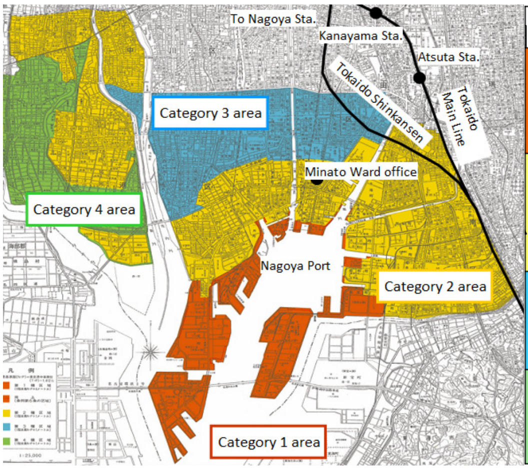


Figure3-8　Measures for controlling flooding flow

C. Measures for reducing damage in floodplain (regulation of land-use, raising floors of buildings, installing electric and machinery equipment at higher places)

Regulatory measures are taken to mitigate property damage in floodplains. These measures include encouraging appropriate land uses so as to mitigate inundation damage, raising the floor levels of houses to make them more flood resistant, and locating power receiving and distribution equipment of hospitals, etc. on upper floors. These measures impose restrictions on private land use and private housing construction.



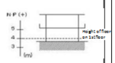
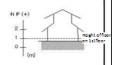
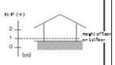
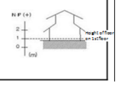
	Description of area	Height of floor on 1st floor	Restrictions on structure	Graphics
Category 1 area	Areas on the sea side from tide barriers. Chiefly coastal reclaimed industrial area.	N/P (+) 4 m or higher	Any wooden structures will be prohibited. In the areas which are within 50 m from the coastal line or river bank and specified by the mayor, construction of any structural buildings with residential rooms, hospitals, welfare facilities for children, etc. will be prohibited. (Structural buildings other than wooden ones, where the floor height of residential spaces, etc. is N/P (+) 5.5m or higher may be constructed.)	
Category 2 area	Areas already urbanized before Isewan Typhoon, and those urbanized after the typhoon are included. The land as a whole is being used for similar purposes.	N/P (+) 1 m or higher	Any residential spaces will be placed on the second or higher floor. The restriction may be relaxed if any of the following three conditions is satisfied: 1: The floor height of one or more residential spaces on the 1st floor will be N/P (+) 3.5m or higher. 2: A structural building with 2 or more stories will be built on the same premises. 3: An evacuation room and facilities will be installed, if the total floor area is 100 m² or less.	
Category 3 area	Areas already urbanized at the time of Isewan Typhoon, and located inland. Thus they do not require strict regulations	N/P (+) 1 m or higher	—	
Category 4 area	Urbanization-restricted areas	N/P (+) 1 m or higher	Any residential spaces will be placed on the second or higher floor. The restriction may be relaxed if any of the following two conditions is satisfied: 1: The floor height of one or more residential spaces on the 1st floor will be N/P (+) 3.5 m or higher. 2: A structural building with 2 or more stories will be built on the same premises.	

Figure3-9　Land use regulation by designating hazard areas

Nagoya City has, based on the lessons from Isewan Typhoon in 1959, enacted ordinances in accordance with the Building Standards Act and designated disaster risk areas.

The city designated 4 types of coastal disaster-prevention areas as the disaster risk areas, laying down the restrictions concerning the heights of the first floor of buildings, the use of architectural buildings, etc., and the structures.

Building code in DHA (Disaster Hazard Area)

Article 39　A local government can, in an ordinance, designate an area prone to tsunami, storm surge, and flood as disaster hazard area.

2　Necessary conditions, such as prohibition of building houses or other restrictions in DHA should be specified under the previous item.

D. Evacuation and evacuation guidance measures (evacuation and evacuation guidance, forecast and warning, evacuation facilities, etc.)

Flood forecasts and information are provided so that local residents can escape safely. Measures in this category include establishing criteria and organizational systems for evacuation advisories and evacuation orders so that people can be safely evacuated; predicting precipitation, river stage, the location and time of occurrence of levee breaches and issuing flood forecasts and warnings; compiling flood hazard maps; and ensuring the availability of flood-free evacuation routes and facilities on elevated ground to which people who have failed to escape in time can use as emergency shelters. It is important to perform communication, evacuation drills and education on a continual basis in each area, rather than only in an emergency, to ensure that local residents know where information is available and how they can escape. Human suffering can be alleviated, but it is generally not possible to mitigate damage to property such as houses.

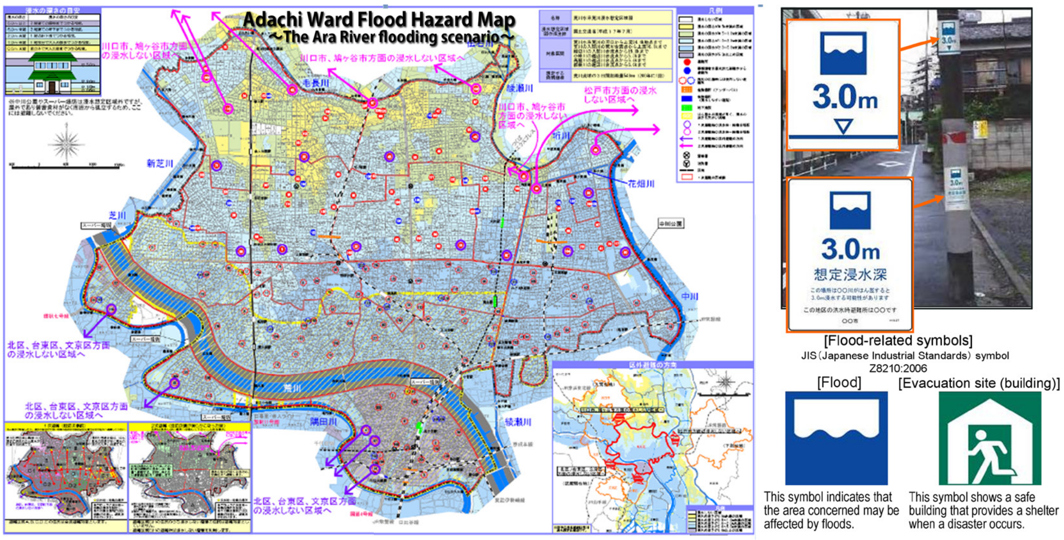


Figure3-10　Compiling flood hazard maps

Efforts such as compiling hazard maps and indicating historical flood levels in town are being made.

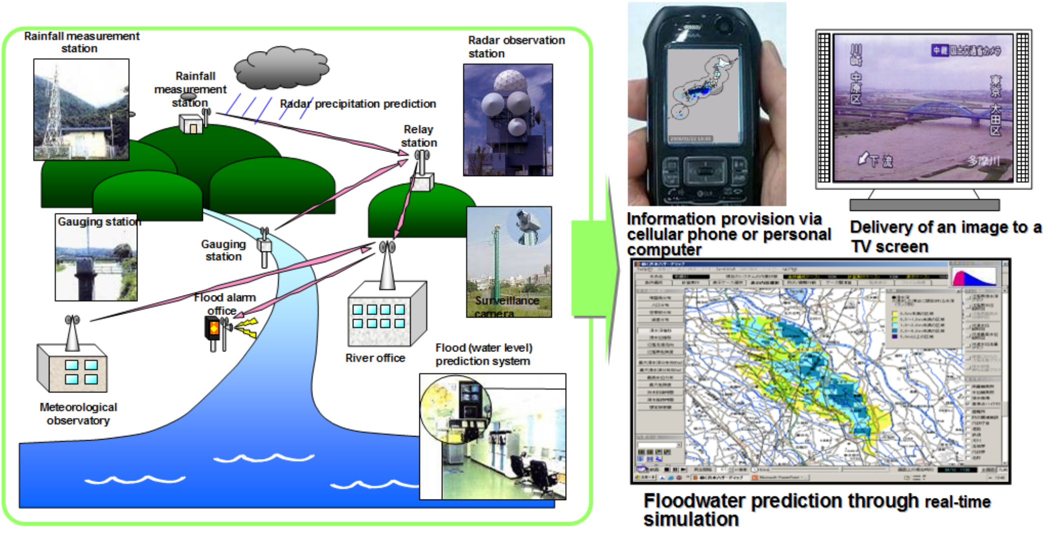


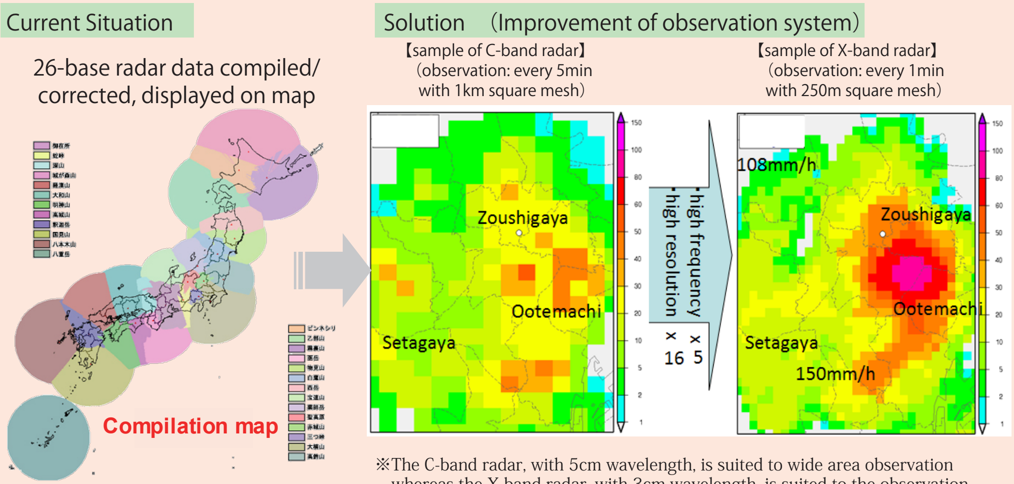
Figure3-11　River information provision

Real-time rainfall and water level information and forecasts are provided through cellular phones, Internet, etc., in order to assist in flood defense activities and evacuation.

【Reference】X-band MP radar

Recent years have frequently seen the damaging flooding of small and medium rivers in urban areas due to a localized heavy rain or a sudden downpour (so-called "guerrilla downpour"). Such downpours bring much rain over a small area in a very short period of time, rapidly raising the river level in a matter of several minutes and causing flood damage and/or water accidents. In order to alleviate the damage caused by them, it is important to detect approaching downpours as quickly and as accurately as possible and provide real-time information.

The River Bureau of the MLIT installed 11 X-band MP radars in the three metropolitan areas by the end of March, 2010 and has commenced experimental operation to ensure proper river management, including the operation of flood control facilities, and adequate implementation of flood fighting and other activities designed to prevent or alleviate flood damage. These radars are capable of observing rainfall with 250 m mesh resolution (compared to the 1 km mesh resolution of the conventional C-band radars) and an observation interval of one minute (compared to five minutes of the conventional C-band radars) (spatio-temporally 80 times denser observation). It is now possible to make detailed and real-time observation of localised and short bursts of rain which could not be detected by conventional C-band radars. It is hoped that the new radars will improve the accuracy of predicting rising river levels and flood risk due to "guerrilla downpours."



C-band radar capable of covering the whole country to manage rivers by monitoring precipitation.

※The C-band radar, with 5cm wavelength, is suited to wide area observation whereas the X-band radar. with 3cm wavelength, is suited to the observation of local heavy rainfall in real time

Figure3-12 Using X-band MP radar to provide information

E. Emergency measures (flood fighting, cofferdam, drainage measures, training, and education)

f there is a risk of inundation, emergency and flexible measures should be taken to reduce damage: (i) securing manpower for flood fighting teams and improving flood drills, (ii) developing efficient and effective flood fighting measures incorporated new techniques, (iii) developing a construction method and a cofferdam system if levees are broken, and (iv) effectively using existing drainage pumps, floodgates, etc. to reduce the area and duration of inundation.

Figure3-13　Flood protection works by flood fighting teams

(Source：Tohoku Regional Bureau, MLIT)

Figure3-14　Drainage of floodwaters (Case of Yoshida River, a Naruse Rivers' tributary)

In view of the lessons learned from the August 1986 flood, a project for building a flood-resistant community along Yoshida River has been launched, and measures including the construction of emergency slucing outlets, marginal strips, secondary levees are being taken.

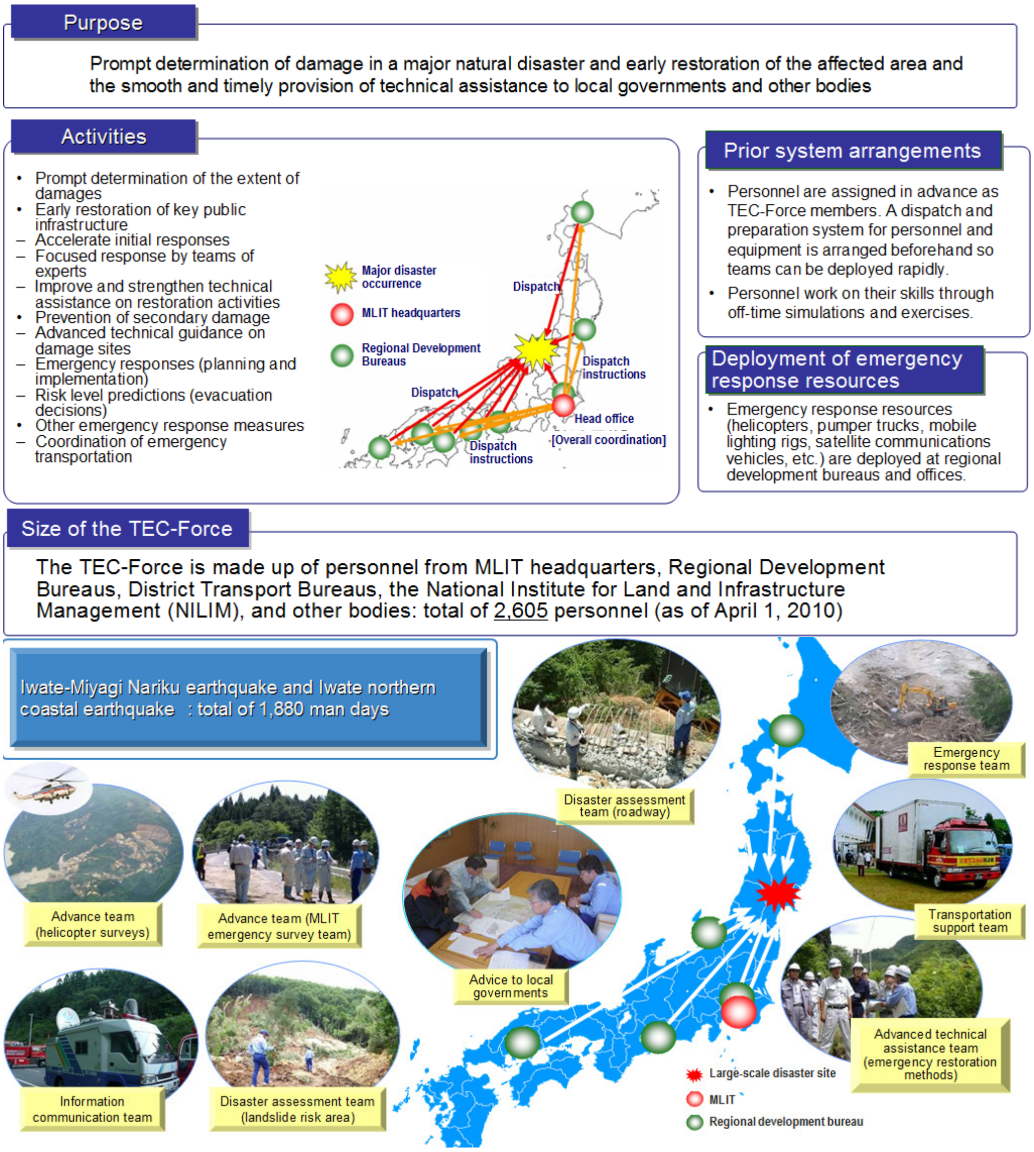
F. Measures for expediting rehabilitation and reconstruction (disaster prevention facilities, transportation network, disaster prevention operation plan, business continuity plan, disposal of flood-generated waste, etc.)

In order to reduce damage, public institutions take measures in advance for expediting rehabilitation and reconstruction after flooding by: (i) securing disaster prevention facilities according to the situations of flooding risks of facilities, flood prevention measures and securement of alternative facilities, (ii) considering routes of roads and railways which can be used in times of disaster, (iii) securing routes accessible to core facilities, (iv) developing measures to be taken by each organization in connection with floods, and (v) implementing measures for continuing operations relating to disasters or high-priority routine work. A flood may generate a considerable amount of waste. It is therefore important to develop procedures for temporarily storing such waste in the affected area or transporting it to other areas, and to prepare final disposal sites and transportation systems.

Also, regarding adaptation measures by facilities of the above A (Measures for reducing risks of inundation) and B (Measures for controlling flooding flow), the reliability of existing facilities should be maintained and improved such as by countermeasures against deterioration, in addition to developing new facilities such as dams or levees.

With respect to Items E (Emergency measures) and F (Measures for expediting rehabilitation and reconstruction), Japan has an institutional system for dispatching state-designated experts (TEC-FORCE) in the event of a disaster to conduct an emergency survey of the damage, take emergency response measures for preventing secondary damage, and provide advice on restoration methods to the local government if it lacks experts and know-how because of the low frequency of disasters and limited organizational capacity.

Although it does not fall into any of the categories mentioned above (A to F), the conservation of the ability of forests to retain sediment is important because the runoff of eroded sediment may cause adverse effects such as flooding of rivers and the occurrence of turbid water.



Purpose

Prompt determination of damage in a major natural disaster and early restoration of the affected area and the smooth and timely provision of technical assistance to local governments and other bodies

Activities

- Prompt determination of the extent of damages
- Early restoration of key public infrastructure
  – Accelerate initial responses
  – Focused response by teams of experts
  – Improve and strengthen technical assistance on restoration activities
- Prevention of secondary damage
  – Advanced technical guidance on damage sites
  – Emergency responses (planning and implementation)
  – Risk level predictions (evacuation decisions)
- Other emergency response measures
  – Coordination of emergency transportation

Prior system arrangements

- Personnel are assigned in advance as TEC-Force members. A dispatch and preparation system for personnel and equipment is arranged beforehand so teams can be deployed rapidly.
- Personnel work on their skills through off-time simulations and exercises.

Deployment of emergency response resources

- Emergency response resources (helicopters, pumper trucks, mobile lighting rigs, satellite communications vehicles, etc.) are deployed at regional development bureaus and offices.

Size of the TEC-Force

The TEC-Force is made up of personnel from MLIT headquarters, Regional Development Bureaus, District Transport Bureaus, the National Institute for Land and Infrastructure Management (NILIM), and other bodies: total of 2,605 personnel (as of April 1, 2010)

Iwate-Miyagi Nariku earthquake and Iwate northern coastal earthquake : total of 1,880 man days

Figure3-15 Technical Emergency Control Force (TEC-Force)

Although it does not fall into any of the categories mentioned above (A to F), the conservation of the ability of forests to retain sediment is important because the runoff of eroded sediment may cause adverse effects such as flooding of rivers and the occurrence of turbid water.

3.2.2 Concept of Appropriate Combinations of Measures

The goal set in 3.1 cannot be achieved through a single measure. It is necessary to combine the optimum options described in 3.2.1 according to each characteristic. When incorporating and examining measures, it is important to understand that prioritized measures must be structurally identified depending on the situation of the countries.

Specifically, based on the basin characteristics and financial capacity, it is important to combine the adaptation options, with a comprehensive consideration of the following points and other points

(i) How widely can river management facilities control flooding by river channel development or flood control facilities?

(ii) To what extent should runoff control measures be implemented in basins?

(iii) How should floods be handled and accepted by communities if flooding exceeds the limit of flood control facilities?

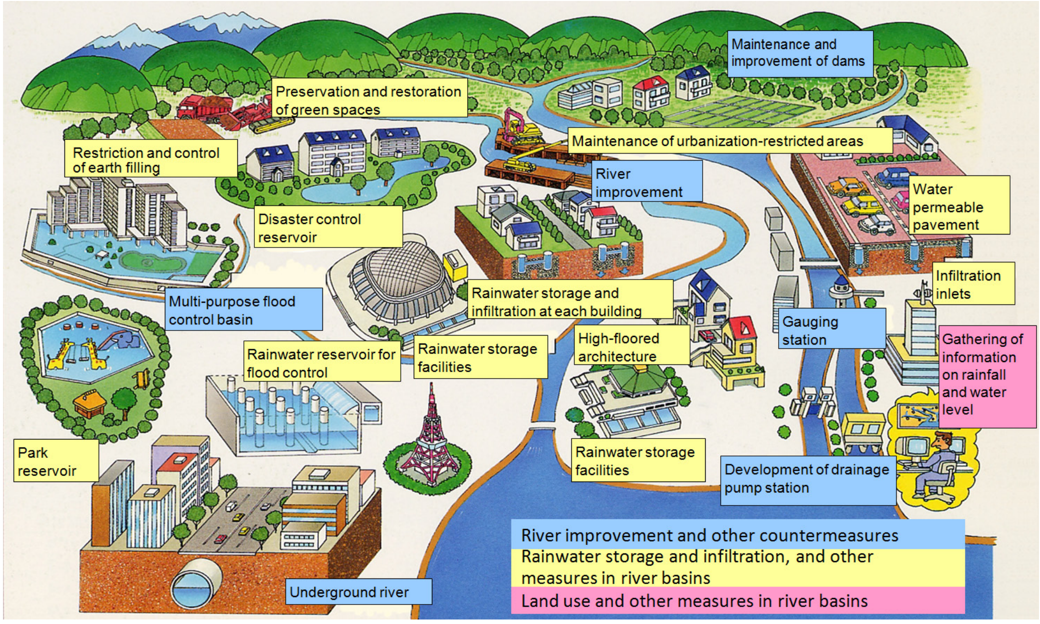


Figure3-16 Appropriate combinations of measures
(Comprehensive Flood Control Measures)

3.2.3 Planning and Assessment of Combinations of Measures

Several specific combinations of measures must be formulated, for several target years described in 1.2.2, and the impacts and effects of implementing such combinations must be assessed.

When combinations of measures are drawn up, in cases where there is an existing plan, it is effective to develop measure options by adding and deleting measures of the existing plan. Also, when facilities have already been developed to some degree, it is important to make effective use of these facilities. Furthermore, it is important to consider based on the history or previously implemented measures of the country.

The effects against flood damage are assessed using the method for evaluating hazards, vulnerabilities, and risks described in 2.5.

In the assessment, the following points must be comprehensively considered: (i) Effects on alleviating damage (life, economic (assets), social functions, etc.), (ii) Costs including maintenance and operation costs, (iii) Impact on communities and environment, and (iv) Reality and safety to be achieved.

In these processes, it is important to take measures as necessary so that the opinions of the local residents are reflected.

3.2.4 Selecting a Combination of Adaptation Measures

An appropriate combination of adaptation measures is selected according to the assessment described in 3.2.3. In addition, when adaptation options for several target years are determined, it is necessary to ensure that the immediate measure to be implemented is consistent with future measures. In such cases, when facility improvement associated with the progression of global warming would be expensive in redevelopment, complicated, or manageable with other reasonable investments, scientifically-valid projection values must be incorporated in the assessment. On the other hand, if adaptation measures can flexibly respond to design external forces, it is important to take adaptive measures according to the progress of climate changes.

3.3 Developing Procedures for Implementing Adaptation Measures

3.3.1 Concept of Procedure for Implementing Adaptation Measures

It is necessary to develop a procedure for implementing a combination of adaptation measures selected from Section 3.2.

When doing this, it is important to develop multiple procedure options, taking into consideration such factors as the prospect for river basin development, investment capacity, and the time and funds available.

3.3.2 Planning and Assessment of Multiple Scheme Options for Implementation Procedures

Multiple schemes for implementation procedures should be planned and assessed.

The implementation procedures should be assessed in a similar manner to that of the combination of adaptation options described in 3.2. When assessing the implementation procedures, it is important to reduce flood damage at an early stage and to consider how to progressively improve the flood control safety balance of upstream and downstream, and right and left banks.

3.3.3 Decision of Adaptation Procedure (Road Map Creation)

A roadmap is created after preparing the implementation procedure based on the assessment as described in 3.2.2.

This roadmap should clearly describe the contents, locations, and effects of the adaptation measures to be implemented, and the procedure of implementing the adaptation measures.

4. Monitoring

With uncertainties such as changes of social conditions and approaches to alleviation measures, projections of changes in external forces have a wide range of values. It is therefore important to carry out monitoring to understand climate changes and to conform to the PDCA cycle described in 1.2.1.

The monitoring procedure is as follows:

- Observation to collect meteorological, hydrological and hydraulic data such as precipitation, water level, stream flow in each river basin
- Collection of river basin data such as land use and vegetation in the river basin and floodplain data such as property and population
- Verification of the differences between observed and collected data and peojected values
- Collection and analysis of meteorological, hydraulic and hydrologic data associated with floods and flooding damage data
- Use of scientific and technological knowledge gained through research and development efforts to improve the accuracy of climate change projection

In view of monitoring results, projected values to be used for the determination of future adaptation measures are reviewed and modified on a regular basis, and adaptation measures based on the PDCA cycle concept are implemented.

It is important to create an environment where the people concerned can use monitoring results easily and efficiently by developing a database of monitoring results and publicizing them in an easy-to-understand manner. By creating such an environment, research and development in the areas of science and technology can be accelerated so as to enhance the accuracy of climate change projection by use of monitoring results and thereby further reduce uncertainty in the coming years.

Figure Example of a database of monitoring results (Global Earth Observation System of Systems)

The Global Earth Observation System of Systems (GEOSS) has a database developed by using various data including earth observation satellite data, ground-based observation data and numerical weather prediction model outputs under the Asian Water Cycle Initiative (AWCI). This system is capable of providing information useful for decision making associated with integrated water resource management tasks such as heavy rain prediction, streamflow prediction and flooding prediction.

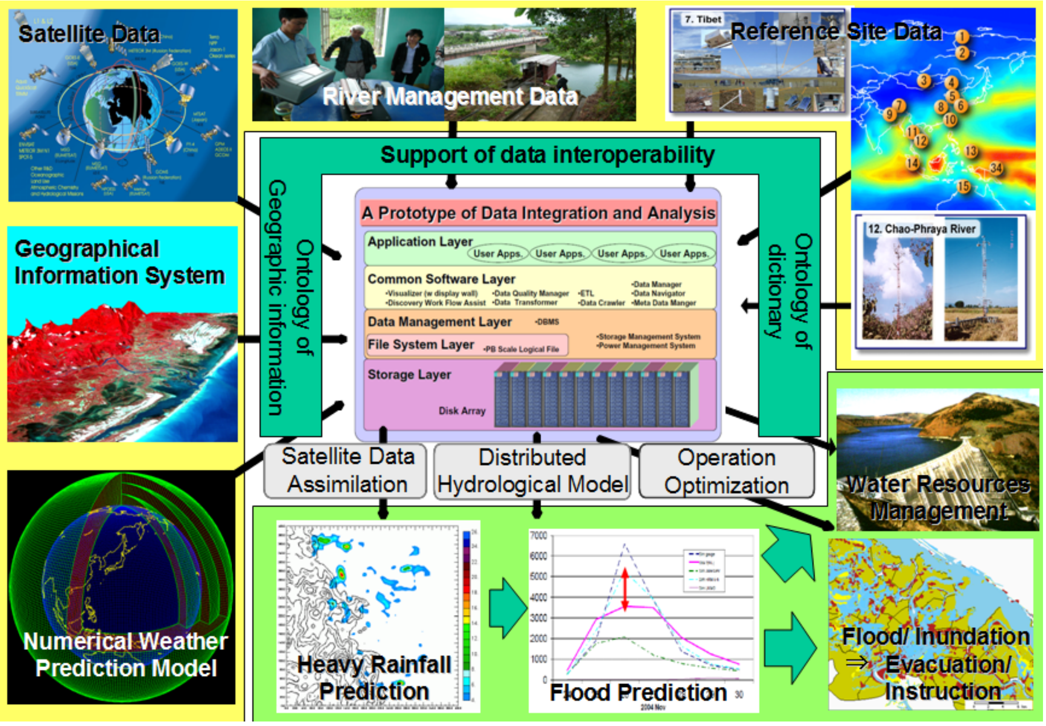


Figure4-1　Example of a database of monitoring results (Global Earth Observation System of Systems)

The Global Earth Observation System of Systems (GEOSS) has a database developed by using various data including earth observation satellite data, ground-based observation data and numerical weather prediction model outputs under the Asian Water Cycle Initiative (AWCI). This system is capable of providing information useful for decision making associated with integrated water resource management tasks such as heavy rain prediction, streamflow prediction and flooding prediction.

Ministry of Land, Infrastructure, Transport and Tourism

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