6. Flood Control Sub-sector

Guideline:

(1) Flood Control (Adaptation Project)
(2) Flood Control (BAU Development with Adaptation Options)

Basic Concept

A. General Concept	The flood control sub-sector would be influenced by climate change. The intensity and occurrence of cyclone will be exacerbated and consequently, flood will intensify and increase. Sea level rise will result to capacity reduction of drainage systems thus prolonging inundation on coastal areas. Application of appropriate measures against flood damage is necessary to reduce flood risk due to climate change. Measures include structural infrastructure means such as development of facilities, non-structural means include evacuation drills, and cross-sectoral programs such as community development. The flood control sub-sector will contribute to mitigating flood damage induced by climate change, through structural and non-structural measures.
B. Vulnerability	1) Major Climate Change Impacts on Flood Control Sub-sector <u>■ Temperature Rise</u> ・Glacier melting will increase the base flow of river, and raise risk of flood. ・Outbreaks of glacial lakes by temperature rise would bring extensive damage in downstream areas. <u>■ Increase/ Intensification of Precipitation and Extreme Events such as Cyclones</u> ・The base flow of river will increase, then flood risk is heightened. ・Flood discharge will increase, which would bring damage even in protected areas by overflowing and destroying river bank. ・There will be some concerns on damage and collapse of dam by overtopping due to increase of inflow to reservoir. ・There will be flash floods, which can cause extensive damage. ・Flood control function of facility will be curtailed by increased sedimentation in reservoir and river channels, induced by increase of soil erosion. <u>■ Sea Level Rise</u> ・The reduction of drainage capacity due to sea level rise will expand inundation area and prolong the inundation duration. 2) Other Factors that Influence Flood Control Sub-sector Associated with Climate Change Impacts ・Population growth, economic development, and intensification of land use lead to development and settlement in flood prone area. ・Deforestation in the river upstream area will change the runoff characteristics of the river. ・Urbanization reduces rainwater infiltration into the ground. ・Increasing opposition against construction of dams leads to suspension of dam development and removal of the existing dams. 3) Adaptive Capacity to Climate Change ・Implementing non-structural measures such as operation of flood forecasting and warning system, preparation of hazard maps, and development of evacuation and precaution, improves adaptive capacity of related government agencies and communities. ・Development of legal systems such as development regulation for the flood prone areas, development regulation of upstream forest to retain water and farmlands to store flooded water, improve adaptive capacity.

	・If adequate public information is implemented, and inhabitants are educated and responsive on disaster and risk management issues, they would implement appropriate precautionary measures and actions in times of disaster, hence, improving their adaptive capacity. ・If the budget and programs for disaster recovery are well in place, disaster response capability of regulatory agencies become high. ・If research institute related to flood control exists and its system is well-organized, the adaptive capacity for climate change is high. ・The existence and enrollment status of insurance and mutual aid systems for flood damage would affect disaster recovery capability. 4) Spatial Distribution of Vulnerability a) Climate Change ・For a watershed branch that can have glacier or snow melt, spatial distribution shall be studied. ・Influence of backwater due to sea level rise shall be studied at downstream or estuarine areas. b) Sensitivity in Flood Control Sub-sector ・Sensitivity varies with installation condition, design conditions, development level, and maintenance level of flood control facilities such as dams, and river dikes. ・Occurrence of river flooding is affected not only by river discharge, but also its cross section, river bed gradient, roughness coefficient, and backwater effect at that point. ・Intrusion of flood flow into the protected areas is influenced by topography. c) Adaptive Capacity ・Each branch watershed differs in runoff characteristics, sedimentation and water retention conditions, and so on, depending on its land use, development regulations, and condition of flood control basin. Hence, adaptive capacity also varies in each branch watershed. ・Disaster resilience capacities vary with the policies of different regulatory agencies. ・Adaptive capacity depends on coping capability and current state of affairs of related local government agencies and communities.
C. Adaptation Measures	Major Adaptation Measures in the Flood Control Sub-sector ■ Development/Improvement of Flood Control Facility ・River improvement (excavation of river channel, levee setting back and embankment, discharge channels and cut-off channels, floodgate, inland water drainage, etc.) ・Control of runoff into river, focusing on rivers (dam, flood control basin, etc.) ・Control of runoff into river, focusing on basins (storage and infiltration facility, etc.) ・Control of flooding flow (secondary levee, open levee, ring levee, flood barrier forest, etc.) ■ Evacuation and Guidance on Evacuation Measures ・Flood forecast, equipment for forecasting and warning systems ・Preparation of hazard maps ・Community organization and training on safety, evacuation and its guidance

	■ Cross-sectoral Measures ・Urban and watershed conservation plans ・Securing facilities and roads for evacuation. ・Elevating building floors, installing electrical and mechanical equipment at higher places
D. Maladaptation	■ Maladaptation in Adaptation Measures ・The areas protected by river dikes seem to be safe. If more inhabitants are convinced that such areas are safe and decide to resettle on dike-protected lands, risk of damage to persons and/or property due to dike failure would increase. ・The awareness of inhabitants on disaster prevention, might be reduced due to the development of flood control facilities, and their responsiveness to possible future changes would weaken. ■ Maladaptation Common to "Business as Usual" Project ・Future change of river discharge, river and sea water level would create shortage of facility capacity, which consequently might cause flood damage.

Guideline: Flood Control (Adaptation Project)

A. General	■ Necessity of Adaptation The target river had been developed with flood control facilities. However, climate change would change precipitation patterns, increase extreme events, and cause backwater effect by sea level rise. Hence, flood occurrence will increase and intensify in the target river basin. ■ Adaptation Measures To increase the flood control capacity in the target area by structural measures such as development of flood control facilities, and non-structural measures such as evacuation. ■ Outcome of Adaptation Measures Flood damage increased by climate change will be mitigated.
B. Vulnerability Assessment	Step 1 1) Assess Past and Present Climate Trends and Risks Collect past meteorological and hydrological records in the target river basin, from meteorological weather stations, hydrological observation stations, and regulatory agencies. 2) Assess Future Exposure to Climate Hazards and Perturbations a) Study Future Weather Conditions Review the national policies related to climate change, and discuss and confirm with counterpart organization the applied climate change scenarios and analysis models, and target year for adaptation measures. Estimate hydrological aspects for the target year based on the analysis results on climate change. b) Study Other Factors related to Socio-economic Changes Study change factors for land use, which is critical to the runoff characteristics of the river, in and around the target area, such as population change and industrial development, through review of documents such as watershed conservation plan, development plan, and land use regulations. Water retention function of the river basin shall be studied in parallel. 3) Assess Future Sensitivity to Climate Change a) Study Past Damage Study the damage of past flood and heavy rains through hearing investigation among stakeholders such as related agencies and inhabitants, and through field investigation in tracing past flood, and then organize flood vulnerable areas. b) Study Present Condition of Facilities and Measures ・Condition of Facilities: Assess the present condition of facilities based on the design capacity and maintenance condition, through inventory survey and review of documents such as reports and drawings for facilities in the target river basin. ・Operating / Functioning Conditions of Facilities: Assess the operation conditions of flood gate and other river structures, through investigation of operation and management records of the facilities, as well as through interviews with stakeholders.

c) Assess Future Sensitivity to Climate Change

Assess future sensitivity to flood damage based on the relationship between past flood damage and meteorological conditions, future climate condition, and condition of facilities, with consideration on future socio-economical change factors.

Step 2

4) Determine and Project Adaptive Capacity to Climate Change

a) Identification of Adaptive Capacity

・Risk on Priority Protection Area (Topography and Flood Control Facilities)

Identify the priority areas to be protected such as densely populated urban areas and important facilities, and study the condition of flood control.

- Conditions of topography of priority areas, and flood control facilities, which are related to the responsiveness to flood.

・Community Based Disaster Management and Crisis Management

Assess the responsiveness against flood occurrence:

- Situations of non-structural measures such as hazard maps, flood forecasting and warning systems, and evacuation drills, which are related to the responsiveness of the local government and inhabitants.
- Maintenance conditions of roads and shelters, which can facilitate evacuation during disaster.

・Disaster Resilience Capability of Regulatory Agency

Assess condition of budget and program of activity for disaster recovery of regulatory agencies.

・Existence and Ability of Research and Development

Assess condition of research and development for flood control.

・Compensation for Flood Damage

Assess the capability to repair damages caused by floods:

- Situations of available insurance or mutual aid system for flood disaster

b) Clarify Exacerbating Factors for Climate Change Impacts

・Land Use and Land Use Regulations

Clarify the land use and related regulatory policies which affect flood damage.

- Land development at flood prone area, which is related to risk of damage from floods.
- Distribution of forest land, which is related to rainwater infiltration and storage.
- Land-use change of farmlands, flood control basins, etc., which is related to the retarding function of the river basin.
- Management of slopes in the upstream areas, with its mismanagement leading to flash floods, due maybe to underdevelopment of retaining and slope protection structures, and vandalism of observation and warning equipment.

Step 3

5) Assess Vulnerability

Assess vulnerability to climate change in the target area by overlapping the factors assessed in Steps 1 and 2. If vulnerability differs within the target area, its spatial distribution shall be studied.

Items	Low ← Vulnerability → High	
Future sensitivity to climate change	Small	Large
Risk of priority protection area	Low	High
Community based disaster management and crisis management	Excellent	Poor
Disaster resilience capability of regulatory agency	Excellent	Poor
Existence and ability of research and development	Exist/ Excellent	None/Poor
Compensation for flood damage	Sufficient	Poor
Land use and land use regulation	Planned	Unplanned

C. Project Evaluation of Adaptation Measures

[Items for Assessment in Project Formulation]

Items	Outcome	Method	Relative Operation and Effect Indicators
Future sensitivity to climate change	Mitigation of flood damage	Economic	・Amount of damage
		Quantitative	・Flooded area ・Flooded houses ・Victim ・Maximum water depth ・Inundation duration
Risk of priority protection area	Mitigation of flood damage	Economic	・Amount of damage
		Quantitative	・Flooded area ・Flooded houses ・Victim ・Maximum water depth ・Inundation duration
Community- based disaster management and crisis management	Improvement of responsive ability on flood disaster	Qualitative	-
Disaster resilience capability of regulatory agency	Improvement of restoration capability after disaster occurrence	Qualitative	-
Disaster resilience capability of regulatory agency	Improvement of restoration capability after disaster occurrence	Qualitative	-
Existence and ability of research and development	Improvement of adaptive capacity	Qualitative	-
Compensation for flood damage	Improvement of restoration capability after disaster occurrence	Qualitative	-
Land use and land use regulation	Reduction of damage in flood prone area	Economic	・Amount of damage
		Quantitative	・Flooded houses ・Victim

[Alternative Items for Assessment in Monitoring and Review]

Type of Measures	Alternative Indicators	Method	Relative Operation and Effect Indicators
Structural measures	Improvement of target return period in the whole river basin or the target area	Quantitative	・Total reservoir capacity ・Water level ・Flood level ・Discharge ・Maximum flood ・Maximum high water level ・Use frequency of facility ・Flood controllable capacity
	Improvement of target return period in priority protection area	Quantitative	・Flood controllable capacity
Non-structural measures	Quantity and quality of land area for storage, infiltration and retarding	Quantitative Qualitative	・Afforestation area
Others	Changes in the number of inhabitants and economical activities in the whole river basin, priority protection area, and flood prone area	Quantitative	-
	Changes in the awareness of stakeholders on flood disaster	Qualitative	-

D. Necessary Consideration for Planning of Adaptation Measures

1) Monitoring and Review

Plan periodical schedule for monitoring of climate condition and review after project implementation. The climate change impacts, which are not considered for the project but have certain risks, shall be included among the monitoring items.

2) Flexibility to Climate Change

Secure flexibility to climate change impacts, which is not considered in the project scope but to address certain risks. The range of flexibility shall be determined with counterpart agencies. The items should include the following:

・Countermeasures for flood damage to facilities (room for extension of flood control capacity)

3) Consideration to Maladaptation

Check maladaptation caused by the project, and plan the corresponding countermeasures.

E. Required Data

	Data	Remarks
B. Vulnerability Assessment		
1) Assess Past and Present Climate Trends and Risks	Past and present meteorology and hydrology	Collect observed data from meteorological and hydrological stations.

	2) Assess Future Exposure to Climate Hazards and Perturbations	Future climate	Estimate future climate using the data from the analysis models and climate change scenarios adopted in the country, based on the observed meteorological and hydrological data in the target area.
		Socio-economic incidence	Collect information about watershed conservation plans, development plans, and land use regulations, related to flood control, in and around the target areas and country from relevant organizations and other agencies.
	3) Assess Future Sensitivity to Climate Change	Past flood damage	Collect and organize the damage condition of each area by flood event. Secular change shall be also collected.
		Design capacity of existing facility	Study the design capacity of each facility based on the existing plan, design standard, design drawings, as-built drawings, etc.
		Condition of existing facility	Study the operating condition of each facility through inventory survey.
		Operation and maintenance record of flood control facilities	Collect detailed operation and maintenance record to study the situation during flood disaster occurrence.
	4) Determine and Project Adaptive Capacity to Climate Change	Risk of priority protection area	Study the vulnerability of priority protection area to flood disaster based on topographical conditions; and study the design capacity and condition of sediment-related disaster prevention facilities.
		State of non-structural measures	Study and review the current state of non-structural measures through interviews with related agencies, and based on related information collected.
		Conditions of evacuation road and shelters	Study and review the condition through interview with related agencies, and based on related information collected.
		Disaster resilience capability of regulatory agency	Study and review the budget and program of activity through interviews with related agencies, and based on related information collected.
		Existence and ability of research and development	Study and review the research activity programs through interviews with related agencies and based on related information collected.
		Existence and enrollment of damage insurance and mutual aid system for flood disaster	Study and review the status through interview with related agencies and based on related information collected.
		Land use and land use regulation	Study present status of land use including differences in land use regulations, and investigate actual condition by site reconnaissance, by using land use maps and satellite images. Study land use regulation by reviewing related information and conducting interviews with related agencies.
	Others		
		Information related to adaptation	Review and study the adaptation policy by reviewing past studies and other information about adaptability to climate change in and around the target area, if available.

Guideline: Flood Control (BAU Development with Adaptation Options)

<table>
<tr><td>A.
General</td><td>■ Necessity of Adaptation Options
It is necessary to increase flood control capacity of the target river, in association with economic growth and land development.
Potential risks of flood disasters in more extended areas, or in greater magnitudes, are likely to occur in the target river basin and areas. The climate change impacts are expected to increase the amount of precipitation, change rainfall patterns, increase frequency and scale of extreme events, and increase backwater effects due to sea level rise.
■ Adaptation Options
Appropriate measures will be implemented within the project with consideration of the increased flood damage associated with climate change.
■ Outcome of Adaptation Options
The expected damages from the flood disaster will be mitigated in the event of climate change.</td></tr>
<tr><td>B.
Vulnerability Assessment (Risk and Change)</td><td>Review the national policies related to climate change, and discuss and confirm with counterpart organization the applied climate change scenarios and analysis models, and target year for adaptation measures. Project hydrological aspects at the planned base year using the analysis results of climate change projection for the target year.</td></tr>
<tr><td>C.
Planning Adaptation Options</td><td>Plan adaptation options that account for future climate change.
Possible options are structural measures such as developing or improving flood control facilities, and non-structural measures such as evacuation drills, which could be implemented individually or simultaneously.</td></tr>
<tr><td>D.
Project Evaluation of Adaptation Options</td><td>[Items for Assessment in Project Formulation]
<table>
<tr><th>Items</th><th>Outcome</th><th>Method</th><th>Relative Operation and Effect Indicators</th></tr>
<tr><td rowspan="2">Future sensitivity to climate change</td><td rowspan="2">Mitigation of flood damage</td><td>Economic</td><td>・ Amount of damage</td></tr>
<tr><td>Quantitative</td><td>・ Flooded area
・ Flooded houses
・ Victim
・ Maximum water depth
・ Inundation duration</td></tr>
<tr><td rowspan="2">Risk of priority protection area</td><td rowspan="2">Mitigation of flood damage</td><td>Economic</td><td>・ Amount of damage</td></tr>
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・ Maximum water depth
・ Inundation duration</td></tr>
</table>
[Alternative Items for Assessment in Monitoring and Review]
<table>
<tr><th>Type of Measures</th><th>Alternative Indicators</th><th>Method</th><th>Relative Operation and Effect Indicators</th></tr>
<tr><td>Structural measures</td><td>Improvement of target return period in the whole river basin or the target area</td><td>Quantitative</td><td>・ Total reservoir capacity
・ Water level
・ Flood level
・ Discharge
・ Maximum flood
・ Maximum high water level</td></tr>
</table></td></tr>
</table>

				・Use frequency of facility ・Flood controllable capacity
		Improvement of target return period in priority protection area	Quantitative	・Flood controllable capacity
	Non-structural measures	Quantity and quality of land area for storage, infiltration and retarding	Quantitative Qualitative	・Afforestation area
	Others	Changes in the number of inhabitants and economical activities in the whole river basin, priority protection area, and flood prone area	Quantitative	
		Changes in the awareness of stakeholders on flood disaster	Qualitative	

E. Necessary Consideration for Planning of Adaptation Options

1) Monitoring and Review

Plan periodical schedule for monitoring of climate condition and review after project implementation. The climate change impacts, which are not considered for the project but have certain risks, shall be included among the monitoring items.

2) Flexibility to Climate Change

Secure flexibility to climate change impacts, which is not considered in the project scope but to address certain risks. The range of flexibility shall be determined with counterpart agencies. The items should include the following:

・Countermeasures for flood damage to facilities (room for extension of flood control capacity)

3) Consideration to Maladaptation

Check maladaptation caused by the project, and plan the corresponding countermeasures.

F. Required Data

	Data	Remarks
B. Vulnerability Assessment		
	Future climate conditions	Estimate future climate using the data from the analysis models and climate change scenarios adopted in the country, based on the observed meteorological and hydrological data in the target area.
Others		
	Information related to adaptation	Review and study the adaptation policy as well as the past studies and other information about adaptation to climate change in and around the target area, if available.

References and Key Different Features

1) Handbook on Climate Change Adaptation in the Water Sector[i]

JICA's approach of development assistance to developing countries with regards to climate change adaptation for water sector (mainly focused on flood control, but also includes water resources, water environments, sediment, and coastal protection) is shown in this handbook.

This handbook (HB) is the main reference for this survey of the flood control sub-sector, and the policies and methods are basically the same with each other in this regard. However, there are some differences between this survey and HB. The differences are as follows:

・The target of the HB is mainly a ,master plan; on the other hand, this survey targets the feasibility study directly leading to loan assistance. The HB gives importance on the flood damage reduction by regional/urban planning and land use control as an adaptation measure in the flood control sub-sector.

・OECD-DAC defined climate change adaptation-related aid as activities that aim "to reduce the vulnerability of human or natural systems to the impacts of climate change and climate-related risks, by maintaining or increasing adaptive capacity and resilience". In this regard, vulnerability should be examined, however the definition and assessment procedure of vulnerability are included but not clarified in the HB. This survey clearly specifies the vulnerability assessment and its study procedure.

・The HB defines the target year as 2040-50 in consideration of the availability of calculation results of GCMs used for IPCC AR4. On the contrary, this survey proposes to conform to the policies of the recipient country, considering that IPCC AR5 will be published in 2013, and much of the countries have already involved climate change in their policies.

・The HB recommends the downscaling of AGCM20 results as a general rule. On the contrary, this survey proposes to conform to the policies of the recipient country, considering that AGCM20 has been proved unsuitable to every region of the world through researches and studies, and much of countries have established their own climate change policy using their own selected models which suit to their countries.

Below is a brief summary of the HB.

Conventional planning based on the premise of stationarity which states that past precipitation pattern will not change over time has become invalid due to climate change. The project formulation approach will be fundamentally different from the conventional one in the following aspects:

・It will deal with a changing climate.

・It will involve projecting future impacts for project formulation and implementation.

・Technologies available for projection and adaptation are being developed day to day, and water management systems will change or must be changed accordingly.

The project formulation approach in flood control sub-sector becomes as follows:

1. Flood Projection

The target year will be set to a year during the 2040-50 period.

The current practice of determining the target return period will be applied.

More than one design rainfall level should be used to allow for flexibility to cope with uncertainties. Such design rainfall levels may include, for example, the current value without taking climate change into consideration; the value calculated using the downscaling models or the average value from the ensemble model.

Runoff analysis will be implemented by following the existing methods.

2. Existing Facilities, Plans, and Management Structure: Identifying Existing Coping Mechanisms

Identify and inventory existing facilities, plans and institutional frameworks for disaster prevention that may be used for adaptation.

(a) Structural measures
(b) Institutional framework
(c) Areas that may not have been identified but need to be identified for implementing community-based measures
(d) City plans and regional development plans

3. Damage Potential and Impact Assessment
Since inundation occurs and is managed in floodplains, it is essential to simulate and analyze the inundation. If data for simulation is insufficient, conduct interviews on the largest flood and yearly floods to date to estimate the inundation depths.
Damage and vulnerability will be assessed through an inundation analysis. In addition to the conventional assessment, the following items shall be examined from the perspective of human security:
・Damage to specific vulnerable groups, including the poor
・Damage to the livelihoods and property of individuals
The detailed mechanisms of glacial lakes outburst are unknown. Priority should be given to identifying dangerous glacier lakes through continuous surveys and analyses and to developing methods and improving their accuracy, with the focus on the following:
・Analyses of glacier lake dynamics and collapse risks using satellite data
・Analyses of the structure, thermal environment, and collapse mechanisms of glacier lakes based on field surveys
・Development of a monitoring system using remote sensing and other technologies

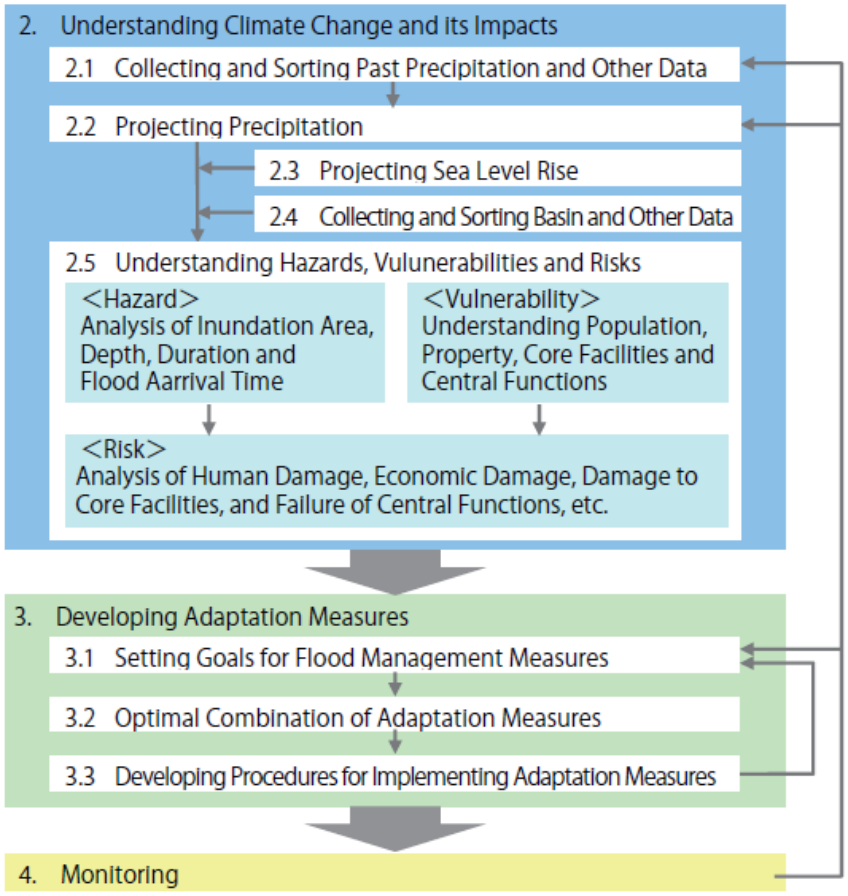
4. Adaptation Planning
(1) River Basin Governance
Adaptation planning involves a wide range of stakeholders and various sectors. It also hinges on voluntary activities on the part of communities. It is therefore important to establish a council or forum made up of stakeholder organizations, experts and academics at the early stages of planning.
(2) Meteorological and Hydrological Observation
Improving and maintaining meteorological and hydrological observations are considered as cross-cutting adaptation measures in the water sector, aiming at the greater accuracy of climate change impact assessment, a deeper understanding of extreme floods, and the development of warning.
(3) Flood Disasters
(a) Target Setting
Target setting is primarily aimed at protection of human lives and minimization of losses. The following steps are adopted as the strategy:
Step 1: Protection of strategic facilities
Step 2: No settlement
Step 3: Community-based disaster management and crisis management
(b) Facilities Planning
Flexible and resilient responses are necessary since the magnitude of disasters will be increasing.
(c) Economic Assessment
Usually, the benefits of intervention will most likely be affected by the impacts of climate change. Yet assessing climate change impacts for each year may be too complicated and impractical. A viable alternative option is be to use the projected benefits at a year halfway between the current year and the target year as the benefits for each year on the assumption that the benefits will change at a fixed rate until the target year.
There are no established methods for quantitatively assessing the improvement of disaster management capacity through non-structural measures such as capacity building for communities

on evacuation. Such assessments have to be made on a case-by-case basis.
(d) Regional/Urban Planning, Land Use Control
i) Risk Zoning and Development Control
・Limit the use by prohibiting settlement in a damage risk zone, or settle after implementing the countermeasures through flood-proof structures such as reinforced concrete or elevating floors.
・Control the development in flood-prone regions
ii) Obligatory Development of Rain-water Penetration Facilities and Flood Control Ponds
iii) Green Belt (Surrounding Open/Green Spaces)
iv) Establishment of a Legal Framework and Its Proper Implementation
v) Organizations, Process and Capacity Development
(e) Community-based Disaster Management and Crisis Management
i) Assessing the Strengths and Weaknesses of a Community (risk and capacity assessment)
ii) Project Planning
(infrastructure development, environmental conservation, establishment of a forecast/warning system, human resources development, development of voluntary organizations for disaster preparedness, dwellings, safety nets, budget)
iii) Project Appraisal
iv) Project Formulation
v) Establishment of a Risk Communication Framework through a Series of Efforts
(4) Measures for the Poor and the Vulnerable
(5) Disaster Insurance
(6) Monitoring (Evaluation and Review) and Maintenance

2) Practical Guidelines on Strategic Climate Change Adaptation Planning - Flood Disasters -[ii]
These guidelines (GLs) describe a framework in developing adaptation measures against the increase 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.

The GLs are highly developed to be practical for master plan and feasibility study of flood control sub-sector in the development assistance. This survey refers much to the GLs and most parts are basically same. The distinctive difference between this survey and GLs are as follows:
・"Vulnerability Assessment" in this survey corresponds to "Understanding Hazards, Vulnerabilities and Risks" in GLs. The definition of vulnerability has been established globally, where the vulnerability shall be assessed by "hazard of climate change", "sensitivity", and "adaptive capacity" that includes non-structural measures and land use regulations. GLs have no clear description about adaptive capacity and its assessment, even though GLs may involve the basic concept of the adaptive capacity. This survey specifies the vulnerability assessment.

The process in developing adaptation measures are shown in the chart below.



Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan (2010), p.1

The following describes the summary of each step.

2.1 Collecting and Sorting Past Precipitation and Other Data

It is necessary to collect and sort long-term precipitation data with consistent quality. These data are also needed to review and verify calculation results replicating the present status with GCM, downscaling, and bias correction methods.

2.2 Projecting Precipitation

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 three scenarios in IPCC AR4 scenarios, i.e., A1B, A2, and B2 have been used predominantly for developing global warming projection. Furthermore, A1B is widely used in projecting global warming impacts and developing adaptation measures.

It is important to use projection calculation results obtained from multiple GCMs capable of accurately reproducing region-specific precipitation phenomena. Statistical downscaling and dynamic downscaling have respective advantages and disadvantages.

2.3 Projecting Sea Level Rise

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.

2.4 Collecting and Sorting Basin and Other Data

Catchment data for runoff analysis, river data for calculation of flood propagation in river channels, and floodplain data for inundation analysis are collected. In addition, hydrological and hydraulic values relating to river flow and flooding such as discharge, water level, and flooding depth, are collected and sorted to compensate for the insufficiency of information about rivers and basins.

2.5 Understanding Hazards, Vulnerabilities and Risks
Flood damage is assessed through a series of runoff analysis, calculations of flood propagation in river channels, and inundation analysis.

3.1 Setting Goals for Flood Management Measures
It is a good practice to estimate changes over a period of about 20 to 30 years. General goals are set such as to "minimize victims" and "avoid paralysis of capital city functions". Based on these goals, after developing and setting adaptation measures, it is important to clearly present and specify goals in terms of time, cost, etc.

3.2 Optimal Combination of Adaptation Measures
It is necessary to carefully evaluate the effectiveness of adaptation measures, taking into consideration the climate characteristics and socio-economic situation of the basin; and financial and legal systems, administrative organizations, and infrastructure conditions of the country.
The optimal measure shall be selected from the formulation and assessment of specific measures, and likewise assessed, based on opinions of the local residents. The major adaptation measures are listed as follows:
A. Measures for reducing risks of inundation (e.g,. excavation of river channels, levee setting back, embankment, dam, and flood control facilities)
B. Measures for controlling flooding flow (e.g., secondary levees, open levees, ring levees)
C. Measures for reducing damage in floodplain (e.g., regulation of land-use, raising floors of buildings, installing electric and machinery equipment at higher places)
D. Evacuation and evacuation guidance measures (e.g., evacuation and evacuation guidance, forecast and warning, evacuation facilities)
E. Emergency measures (e.g., flood fighting, cofferdams, drainage measures, training, and education)
F. Measures for expediting rehabilitation and reconstruction (e.g., disaster prevention facilities, transportation network, disaster prevention operation plan, business continuity plan, and disposal of flood-generated waste)

3.3 Developing Procedures for Implementing Adaptation Measures
It is important to develop and assess multiple procedure options to clearly show the implementation procedure of the adaptation measures.

4. Monitoring
It is important to carry out monitoring to understand climate changes and to conform to the PDCA cycle considering the uncertainties of climate change impacts.

[i] JICA. (2010). Handbook on Climate Change Adaptation in the Water Sector: A Resilient Approach that Integrates Water Management and Community Development

[ii] Ministry of Land, Infrastructure, Transport and Tourism, Japan. (2010). Practical Guidelines on Strategic Climate Change Adaptation Planning -Flood Disasters-