VIETNAM INSTITUE OF METEOROLOGY, HYDROLOGY AND ENVIRONMENT

Technical Guidance for the

Assessment of Climate Change Impacts and the Identification of Adaptation Measures

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Vietnam Institute of Meteorology, Hydrology and Environment

Technical Guidance
for the
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The **Technical Guidance for Assessment of Climate Change Impacts and Identification of Adaptation Measures** was developed by the Institute of Meteorology, Hydrology and Environment (IMHEN) with the support from the United Nations Development Programme (UNDP),.

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Introduction

Climate change is one of the greatest challenges to Vietnam in achieving sustainable development, hunger eradication and poverty reduction. Particularly, the Mekong River Delta is the region which is most vulnerable to sea level rise.

Being aware of climate change challenges, the Government of Vietnam by Decision No. 158/2008/QD-TTg, dated 2nd December 2008 had approved the National Target Program to Respond to Climate Change (NTP-RCC). The approval of the NTP-RCC is one of the first successful activities of Vietnam's effort to respond to climate change for the purposes of achieving sustainable development. Two of the eight important activities of the NTP-RCC include the: (i) Assessment of climate change impacts on sectors and local areas and the (ii) Identification of response measures.

On 13th October 2009, the Ministry of Natural Resources and Environment approved the Official Dispatch No.3815/BTNMT-KTTVBDKH on the Guidance Framework for the Development of Action Plan to Respond to Climate Change, in order to guide the ministries, sectors and local authorities to develop their action plans to respond to climate change.

However, climate change is new not only for Vietnam but also for the global community, and hence many local authorities encounter significant difficulties in the implementation of two activities: (i) Assessment of climate change impacts on sectors and local areas and the (ii) Identification of response measures

In order to assist the local authorities with the techniques and methods of assessing climate change impacts and proposing response measures, the Ministry of Natural Resources and Environment assigned the Institute of Meteorology, Hydrology and Environment to develop the technical guidance on the *"Assessment of Climate Change Impacts and Identification of Adaptation Measures"* with the financial support from the United Nations Development Programme (UNDP). This Technical Guidance is developed in the way that is easy to understand and apply in the actual circumstance of the local area.

We hope that this Technical Guidance can contribute to addressing the difficulties and barriers during the development of the Action Plan to respond to climate change.

The Ministry of Natural Resources and Environment expects to receive comments from experts, scientists and the managers from Ministries/sectors and localitiesto continuously supplement this Technical Guidance.

Sincere thanks.

Dr. Tran Hong Ha

Vice Minister of the Ministry of Natural Resources and Environment

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Chapter 1. Introduction

1.1. The basis for the Technical Guidance

According to the National Target Programme to Respond to Climate Change (NTP-RCC) approved by Decision 158/2008/QD-TTg dated 2nd December 2008 by the Prime Minister, the development of the action plan to respond to climate change is one of the most important tasks of the Ministries, sectors and local authorities. In order to successfully develop the action plan, the cities/provinces have to implement two important tasks, which are: (i) Assessment of impacts and vulnerability due to climate change and (ii) Identification of appropriate response measures.

Currently, the Ministry of Natural Resources and Environment approved *"The Guidance Framework on Development of the Action Plan on Climate Change Response for Ministries, Sectors And Local Authorities"* (henceforth, the Guidance Framework) in 2009. The Guidance Framework has assisted policy-makers, responsible officers and climate change-related stakeholders with the overview of the action plan to adapt to climate change. However, it is necessary to develop a more detailed guidance on the method of assessment of climate change impacts and identification of specific adaptation measures.

From that perspective, the Institute of Meteorology, Hydrology and Environment (IMHEN) was assigned by the Ministry of Natural Resources and Environment (MoNRE) to develop the Technical Guidance on *"Assessment of Climate Change Impacts and Identification of Adaptation Measures".* The project *"Strengthening National Capacities to Respond to Climate Change, Reducing Vulnerability and Controlling GHG Emissions"* (CBCC project), which is sponsored by the UNDP and managed by IMHEN, has cooperated with the team of consultants to develop this Technical Guidance to implement Section 2.4 and 2.5 of the Guidance Framework.

It is required that the Technical Guidance should be easy to understand and apply in the circumstance of Vietnam and for individuals/organizations, which have been implementing climate change response activities at the provincial level.

This Technical Guidance will be one of the important references for the preparation of the climate change response action plan.

1.2. The scale of the Technical Guidance

The Technical Guidance was developed for the following target audiences:

- The organizations/agencies/individuals directly or indirectly participating in the formulation, implementation, monitoring or coordination of climate change response action plans at city/provincial level;
- The organization/agencies/individuals responsible for the state management whose daily duties are related to climate change, e.g. water resources, hydropower, water transport, aquaculture and agriculture.

The Technical Guidance also aims to assist the state, non-governmental organizations and the private sector to:

- Implement the climate impact assessment at city/provincial level;
- Prioritize climate change impacts for consideration;
- Identify adaptation measures;
- Select appropriate adaptation measures.

The timeframe for the assessment of climate change impacts and vulnerability is 20 years. This timeframe is appropriate for the orientation of the socio-economic development of the city/province.

The Technical Guidance describes the approaches, the methods and the implementation steps and a number of typical examples for the assessment of climate change impacts and the identification of adaptation measures for cities/provinces. The Technical Guidance provides an overview of the methods used in the assessment of climate change impacts as well as the weaknesses, strengths and the application scale for each method. Based on that, the officers and experts can select the method which is most appropriate to the conditions and prioritized sectors of their local areas. Important criteria for the selection of assessment methods include the data required, the detailed level of the result, cost, time, capacity and the demand for expertise.

In order to apply this Technical Guidance in reality, the users will need the support of experts and will need to be trained on the assessment method mentioned in this Technical Guidance.

1.3. Glossary of terms

Weather is the state of the atmosphere at a certain place which is identified by the following factors: temperature, pressure, humidity, wind speed, precipitation, etc.

Climate is defined as the “average weather” over a period of time (usually 30 years).

Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external

forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Response/Coping refers to the activities of human-beings to adapt and mitigate the climate change.

Adaptation to climate change refers to adjustments in natural or human systems in response to actual or expected climatic change or their effects in order to moderate harm or exploits beneficial opportunities.

Mitigation is the activity to reduce the level and intensity of the GHG emissions.

Vulnerability due to climate change impacts is the degree to which a system is susceptible to, or unable to cope with adverse effects of climate change including climate variability and extremes.

Climate change scenario is the scientific-based assumption about the future trends of the relationship amongst socio-economic development, GHG emissions, climate change and sea level rise. It is noted that climate change scenarios only provide the relationship between socio-economic development and climatic system and hence it is different from weather and climate forecast.

Sea level rise is an increase in the mean level of the ocean, not including tide and sea level rise due to storms. Sea level rise at a certain place can be higher or lower than the global mean level due to the difference in the sea water temperature and other factors.

Prioritized activities are the urgent activities, which should not be postponed in implementation otherwise the vulnerability or cost will increase in the future.

Mainstreaming/Integration is the activity of adjustment and supplementation of development plans, including the direction, policies, mechanisms and organizations related to the implementation of development plans, the activities and outputs of the plan as well as the methods and conditions to implement the development plans to suit the climate change trend, extreme events and their short-term and long-term impacts on the development plan.

Climate impact assessment is research to identify the positive and negative impacts of climate change on the environment and socio-economic activities of the local area. Climate impact assessment also includes the identification and assessment of the adaptation measures.

Vulnerability assessment is the assessment of the vulnerability of an, (a number of) object(s) (communities, regions, group of people or socio-economic/sectoral activities) due to climate change impacts. The level of vulnerability depends not only

on the exposure to climate change but also on the adaptive capacity of that object. The assessment result is presented on the matrix table and the map showing the region/sector vulnerable to climate change.

1.4. The structure of the Technical Guidance

The Technical Guidance includes four main chapters and a Conclusion.

- Chapter 1: provides an overview of the basis, objectives, the scale of application and main glossaries used in the Technical Guidance;
- Chapter 2: gives and overview of the climate change impacts in Vietnam, the characteristics of impacts of climate change on typical geological regions and sectors, which may suffer serious impacts of climate change and need to be prioritized in terms of climate impact assessment;
- Chapter 3: presents the methods of assessment of climate change impacts and vulnerability. The chapter describes the approach, the steps and the content of climate impact assessment. The tools used for climate impact assessment are listed in Appendix A;
- Chapter 4: presents the methods of assessment and selection of the adaptation measures for the most vulnerable sectors and groups. This chapter represents the approach, the process and tools to assess the effectiveness of adaptation measures. The specific adaptation measures for sectors and geological regions are listed in Appendix B;
- Conclusion: summarizes the content of the technical guidance and provides the implementation group to assess climate change impacts.

Chapter 2: Overview of climate change impacts

2.1. Main impacts of climate change

According to the *Climate Change and Sea Level Rise Scenario for Vietnam* (June, 2009) of the Ministry of Natural Resources and Environment, the main manifestation of climate change includes the increase of global temperature, the change in precipitation and sea level rise.

The change of temperature, precipitation and sea level rise according to the low emissions scenario (B1), the medium emissions scenario (B2) and the high emissions scenario (A1FI) for climatic regions of Vietnam are also detailed in this Technical Guidance (from Section 3.3.2 'Steps for climate impact assessment at the provincial level', page 13) to Section 3.3.2 'Step 4', page 17).

The seven main climatic regions in Vietnam include: the Northwest, the Northeast, the Red River Delta, the North Central Coast, the South Central Coast, the Highlands and the Southern area.

The change in temperature, precipitation and sea level rise due to climate change will impose direct/indirect and positive/negative impacts on the economy, society and environment. The following Table 2.1 will demonstrate several examples of the impacts of climate change.

2.2. Climate change impacts according to geological regions

This section introduces the main characteristics of climate change impacts on the geological regions of Vietnam and the sector/sub-sectors in each region (Table 2.2). The geological regions described in this section include: the coastal and island area, the delta area, the mountainous and midland area and the urban area.

2.2.1. The coastal and island area

The coastal and island area of Vietnam can be divided into three parts: the North, the Central area and the South. These three areas are usually impacted by climate-related events such as storms and depression (especially the Central area); floods and land erosion (especially the Northern and Central coastal area). Besides, many cities and service sectors are located in the coastal area and hence most of the sector and socio-economic activities are impacted by climate change. Two sectors, which may be mostly impacted by future climate change in the coastal areaare tourism and aquaculture.

2.2.2. The delta areas

Two main delta areas in Vietnam include the Red River Delta and the Mekong River Delta, which are low areas and hence usually impacted by inundation. The Northern and Central delta will be significantly impacted by tropical storms, tropical depressions, floods and land erosion in the rainy season and by drought in the dry season. According to the projections, in future, sea level rise will impose the most significant impact on the Mekong River Delta.

2.2.3. The mountainous and midland area

The mountainous and midland area of Vietnam can be divided into the following regions: the Northern mountainous and midland area; and the Central and Highland mountainous area. Those areas are usually impacted by the floods, flash flood and land erosion, forest fire and drought (especially the Northern and Central mountainous areas). Climate change exerts considerable impacts on food security, forestry, transport, environment/water resources/biodiversity, medical/community health/other social issues in the mountainous and midland areas.

2.2.4. The urban areas

In Vietnam, the municipalities are concentrated along the coastal and delta areas. The relative scale of the municipalities in the mountainous and midland areas is small. However, they play a vital role in the national network of municipalities.

Basically, cities will be exposed to the impacts of climate change in the region where these cities are located. Most of the large cities are situated in the coastal and delta areas and thus sea level rise, storms and floods have the most significant impacts. Most of the socio-economic activities in the urban areas are affected by climate change. Primarily, municipalities are the centers of the economy, culture and politics, therefore the vulnerability and the economic, social, environmental and infrastructural damages are even more significant. The social issues in cities are more complicated and for that reason, a variety of communities in the urban area are vulnerable to climate change. However, the response capacity of the urban area is always higher than that of the rural area because of the higher awareness of the community, the greater management capacity and better infrastructure.

Table 2.1. Several examples of climate change impacts

1. Changes in temperature (e.g. increased temperature in the hot season, deceased temperature in the cold season, higher maximum temperature and greater numbers of heat waves with higher intensity, etc.)

- Increasing evaporation, decreasing water balance, which will worsen the drought situation;
- Increasing infectious diseases, the mortality cases and the chronic diseases in old people;
- Reducing the productivity and output of plantations and breeding animals (in some cases, the productivity of plantations in some regions can increase if supplied with sufficient water);
- Placing higher pressure on livestock and wild animals;
- Increasing the risk of forest fire;
- Increasing the demand for electricity for cooling and decreasing the stability and working life of the electricity supply system.

2. Changes in the precipitation (higher precipitation in the rainy season and lower precipitation in the dry season) can lead to:

- Increasing the flooding flow and inundation;
- Increasing the capacity of hydropower generation;
- Increasing the risk of land erosion and land slide;
- Increasing drought and saline intrusion in the dry season;
- Changing the eco-system of river basins and wetlands.

3. Increasing intensity and frequency of storms can result in:

- Increasing the inundation in the coastal and riverside areas;
- Increasing the risk of damage to people, infrastructure and socio-economic activities;
- Increasing the risk of damage in the coastal eco-systems.

4. Sea level rise can lead to:

- Inundation in the coastal and riverside areas;
- Further saline intrusion, which will impact on the activity of water supply, agriculture and aquaculture;
- Reduce the capacity for water drainage.

Table 2.2.Sectors and groups impacted by climate change according to the geographical locations

Geographical region	Climate change impacts	Sectors impacted by climate change	Vulnerable groups
The coastal and island areas	▪ Sea level rise ▪ Increased storms and tropical depression ▪ Increased floods and land erosion (the Central area)	▪ Agriculture and food security ▪ Aquaculture ▪ Transport ▪ Construction, infrastructure, urban/rural development ▪ Environment/water resources/biodiversity ▪ Community health/other social issues ▪ Services, business and tourism	▪ Poor farmers and fishermen in the coastal areas Old people, children and women
The delta areas	▪ Sea level rise ▪ Increasing storms and tropical depression ▪ Floods and land erosion (the Northern area) Saline intrusion	▪ Agriculture and food security; ▪ Aquaculture ▪ Industry ▪ Transport ▪ Construction, infrastructure, urban/rural development ▪ Environment/water resources/biodiversity ▪ Community health/other social issues ▪ Services, business and tourism	▪ Poor farmers ▪ Old people, women and children
The mountainous and midland areas	▪ Increasing floods and land erosion ▪ Increasing climatic extreme events ▪ Increasing temperature and drought (in the Highland and the Northern and Central mountainous area)	▪ Food security ▪ Transport ▪ Environment/water resources/biodiversity ▪ Services, business and tourism	▪ The mountainous people, especially the ethnic minorities ▪ Old people, women and children.
The urban areas	▪ Sea level rise ▪ Increasing storms and tropical depression ▪ Increasing floods and inundation ▪ Increasing temperature	▪ Industry ▪ Transport ▪ Construction, infrastructure, urban development ▪ Environment/water resources ▪ Community health/other social issues ▪ Services, business and tourism ▪ Energy	▪ Poor people and workers ▪ Old people, women and children ▪ Labour ▪ Immigrants

Chapter 3. Methods for assessing the impacts of climate change

3.1 Approach

Climate change impact assessment is the determination of the effects caused by climate change. It should be noted that, in addition to the adverse effects, climate change can have beneficial effects.

Currently, there are many approaches to assess the climate change impacts. For example, according to the Intergovernmental Panel on Climate Change (IPCC), there are three approaches: impact approach, interaction approach and integrated approach. Each approach has its own advantages and disadvantages. The selection of suitable approach depends on many different factors such as assessment requirements, scope, timeframe, and available resources.

To simplify, these Guidelines recommend the following approaches:

- Firstly, assess the impacts of climate change at present (corresponding to the current socio-economic conditions, the environment);
- After that, evaluate the impacts of climate change in the future (corresponding to the climate change scenarios and socio-economic conditions, and the environment in the future - following the timeframe);
- The assessment of climate change impacts in future should be carried out according to different climate change and sea-level rise scenarios and different local socio-economic development scenarios;
- The assessment of climate change impacts should be updated when climate change and sea level rise scenarios are updated or when there is any important adjustment in strategies, policies, plans, sector development and socio-economic development planning of the locality;
- The assessment of climate change impacts can be implemented according to sector, geographic area, ecosystem boundaries or river basins etc. Within the context of a provincial plan, the approaches based on geographical area and sectors are recommended. For a province/city, an **overall assessment** for the entire area should be carried out first. On that basis, the **in-depth assessment** will be implemented for the sectors in province/city and the areas which are most likely vulnerable by the impacts of climate change;
- The assessment of climate change impacts requires the participation of local stakeholders. The community plays a particularly important role in the evaluation of climate change impacts at the present time;

- Gender equality should be considered in the process of the climate change impact assessment.

3.2. Organizing the implementation of a climate change impact assessment

In terms of implementation, the assessment of climate change impacts should be carried out by a local climate change working group[1] (or the action plan drafting group as proposed in the action plan guiding framework) with the support from experts. The assessment for each sector should involve local experts and specialists, who have in-depth knowledge on that sector and ensure their participation. The members of the working group should be trained before starting the assessment.

This working group should be coordinated by the Department of Natural Resources and Environment (or by the Coordination Office for Climate Change of the province/city if any) and include technicians of local departments and agencies that are concerned (the most important departments are the Departments of: Agriculture and Rural Development; Construction; Transport; Planning and Investment; Finance; Health; Tourism; and Industry), the Provincial Disaster Management Committee, social organizations such as the Red Cross, the Women's Union, the Farmer's Union, Universities, research centers involved in the area.

Due to the difficulty of operation of a large-scale group, the working group should be divided into two levels: a **main working group** (including members of the departments, sectors, agencies, important organizations, which are directly related to climate change issues) and an **extended working group** (including all members as stated above). The main working group will directly participate in the assessment, while the extended working group will play supporting role providing information, criticism, comments and suggestions for the main working group.

In addition, the impact assessment, especially the assessment for the present time should have the participation of the local people and communities in the vulnerable areas. The community members will take part in the assessment process with the support of the core members of the working group and experts. Besides that, they should be trained for various approaches and in assessment methods.

Before conducting the assessment, the working group should develop a detailed plan. Members of the group should be assigned to a specific and clear task. Besides independent working time, the members of the working group should hold periodic

[1] This guide assumes that this workgroup has been established in the first step of the planning process to deal with climate change. The technical assessments such as assessing the impact of climate change on the hydrological system should be implemented by the consulting organization and specialists. The working group should participate only in a supporting role, providing information, comments and learning.

meetings to discuss and make agreements on the issues arising in the assessment process.

The working group should consult with the stakeholders when necessary, to ensure that the conclusions of the impact and vulnerability assessments are accurate and suitable with the local conditions.

3.3. Climate change impact assessment process

3.3.1. Position of impact assessment in the action planning process for climate change response

According to the *"Guideline Framework on Developing the Action Plan Responding to Climate Change for Ministries, Agencies, Localities"* of the Ministry of Natural Resources and Environment in 2009, the content of the climate change response plan includes the steps from: *Initiatives, Implementation Preparation* to the *Approval* and announcing an *Action Plan for Climate Change Response*. The planning processes for climate change response are summarized in **Figure 3.1.**

Figure 3. 1. Planning processes to cope with climate change

1. Initiate and prepare for implementation
2. Determine the objectives of an Action Plan
3. Plan to develop the Action Plans
4. Collect information and baseline data
5. Assess the impacts of climate change
6. Identify solutions for climate change response
7. Draft the Action Plan
8. Collects comments
9. Approve and announce the action plan to respond to climate change

This Technical Guide focuses on the impact assessment for climate change and identification of adaptation solutions, corresponding to step 5 and 6 in **Diagram 3.1**.

Figure 3. 2. The process of assessing the impact of climate change

Step 1: Identify climate change and sea level rise scenarios

Step 2: Identify development scenarios

Step 3: Identify prioritized sectors, objects and scope of the assessment

Step 4: Select and analyse tools for climate change impact assessment

Step 5: Evaluate the impacts of climate change, sea level rise according to scenarios:

- **Assess the impacts on the natural environment**
- **Assess the impacts on the socio-economy**

Step 6: Assess risk damage level due to the impacts of climate change

Step 7: Evaluate adaptation ability to the risks and vulnerability

3.3.2. Steps to assess the impacts of climate change for the provincial level

To assess the impact of climate change, the instruction for a seven-step process is given in Figure 3.2:

The implementation contents and methods are described in each step below:

Step 1: Identify climate change and sea level rise scenarios

- The climate change scenario is a scientific assumption about future changes in climatic parameters, such as temperature, precipitation, sea level rise. These scenarios show the relationship between the socio-economic, greenhouse gas emissions, climate change and sea level rise.
- The official climate change and sea level rise scenarios for Vietnam was issued by the Ministry of Natural Resources and Environment (MoNRE) in June 2009 (see *'Climate change and sea-level rise scenario for Vietnam',* MoNRE, 2009, 34 pages). This considers three emissions scenarios: low, medium and high. The scenario described changes of climate in the 21st century compared to the period 1980-1999 for the country and seven major climatic regions: Northwest, Northeast, Northern Plains, North Central Coast, South Central Coast, Central Highlands and the South.
- Climate change scenarios, especially sea level rise for Vietnam will be updated in 2010 and 2015 according to the Roadmap in the National Target Program to

respond to climate change. The impact and vulnerability assessment should be reviewed and updated as these new scenarios are published.

- The climatic parameters described in the official climate change scenario for Vietnam include mean annual temperature rising (^{o}C), annual precipitation changes (%) and sea level rise (cm). The changes in temperature and precipitation are described for 4 periods: December to February, March to May, June to August, and September to November.
- To apply climate change scenarios for the provincial level, we perform the following tasks:
    - Identify the main climatic parameters for sector and research objects. For example, the number of rainy days in a month or the number of periods with temperature exceeds 35^{o}C, might be chosen for considering the impact of climate change on tourism.
    - Choose the climate change, sea level rise scenario for local from the national scenario (for example, taking national climate change, sea level rise scenario of Southern Region for Can Tho City).
    - Depending on the requirements and capabilities, additional detailed calculations could be performed based on the official national scenarios for a specific locality.
- The climate change scenario has **uncertainty**. In fact, different climatic models can provide calculation results on climate change with huge differences. Therefore, instead of relying on the specific results of scenarios, we should rely on the trend and the range of the climate change variables.
- The *Climate Change and Sea Level Rise Scenarios* issued by the Ministry of Natural Resources and Environment used average values of climatic parameters (e.g., average temperature, average seasonal or annual rainfall). The extreme climate factors have not been mentioned (e.g., the change of the extreme high-temperature, extreme low-temperature, number of days of heat waves, cold waves, etc.). In the scenario for sea level rise, only the average for sea level rise was mentioned, other dynamic factors such as sea level rise due to storm surge, monsoon, tides, waves, currents from upstream were not presented.
- When calculating the impact of climate change for a specific locality, additional calculations should be performed in order to make more detailed scenarios for those areas. Hydrological and hydraulic models are applied to provide important information to assess the impacts of climate change for a province or a city, such as precipitation change (under the selected climate

change scenario), sea level rise and other dynamic factors. The selection and application of those models should be implemented by consulting agencies.

- Based on the above scenarios, this Guidelines propose three climate change scenarios correlated to three situations: Low (Slight change), Medium (Moderate change) and High (Major change). The High scenarios can cause more risk and involve more than one factor, which occur and impact simultaneously (e.g., typhoons, sea level rise and heavy rains occur at the same time). For instance: according to a selected timeframe (for example, year 2050), we can choose three precipitation and temperature scenarios corresponding to the Low emission scenario (B1), medium (B2) and High (A2) or three sea level rise scenarios corresponding to scenario B1, B2 and A1FI to evaluate.

Step 2: Identify the development scenarios

- The development scenarios[2] are scenarios which describe the overall socio-economic development for a province, city or sector, which are developed from:
  - The past development trend;
  - The direction, planning and development plan of the region in the future;
  - Research related to local development trends.
- Based on the above information, the climate change working group will develop a (or a number of) local development scenario(s) with a preset evaluation time (assumed to be 2030). Each scenario will describe and provide information on the development in 2030, taking into account the interaction between cultural, economic, political and social factors.
- If there are two or three development scenarios, each scenario should represent different development trends. For example: a **high development scenario** (exceeds the expected development plan of the city); an **average development scenario** with many challenges (growth is slower than expected, there are many barriers to the economy, society, the environment), etc.
- In order to make these scenarios most practical and realistic, the development of the scenarios needs the support from experts and consultation from local stakeholders.

[2] Different scenarios describe different conditions in the future. That is not a prediction but the assumption that is based on the current available data and scientific information.

Step 3: Identify priority sectors, objects and scope of assessment

- The priority sectors and objects are defined as the sectors and objects that the climate change impact assessment should focus on. These sectors and object groups are sensitive to climate change or have poor adaptation capabilities to climate change. Because there are limits to the amount of time and resources, priority should be given to the assessment of the climate change impacts on these sectors and objects.
- The **spatial extent** is the boundary of the area in which the implementation of impact assessments is carried out. Spatial extent is usually determined according to (1) the purpose of the assessment, (2) the existing data, and (3) the administrative, ecosystem and climate boundaries (see Table 3.1). The determination of spatial extent is relative because the assessed area still has interactions with surrounding areas.

Table 3. 1. Spatial extent of climate change impact assessment

○ Administrative units: districts, cities, provinces
○ Geographical units: lake, river basins, coastal, estuarine
○ Ecosystems: lagoons, mangroves, desertification land, the tidally influenced areas
○ Climatic zones: desert, monsoon-influenced areas

- The **time range** is the time intervals and milestones for assessing the impact of climate change. Time range is determined by three main factors: (1) the purpose of assessment, (2) the reliability of methods and (3) the available data. It should be noted that, the longer the time range is, the less accurate the estimation of change in the future will be.
- Because the impact assessment at the provincial level has to take the national climate change scenario as a basis while the national scenario is not detailed enough, these guidelines suggest that localities choose two milestones, which are year 2025 and the year 2040 for evaluation. The reasons to choose these milestones are: firstly, for 2025, we still can use the parameters in the local socio-economic development plan; secondly, 2040 is not too far to see the effects of climate change.
- The priority sectors, subjects and scope of the assessment can be determined as follows:

- Refer to similar studies and expert's opinions in order to list the sectors and objects which need assessment as well as the spatial extent and time range of the assessment. (Similar studies include the studies of the climate change impacts, the studies of vulnerability assessment related to poverty and natural hazards, the socio-economic development of the locality).
- Consult with the local stakeholders in order to issue the final decision. Meetings, consultation workshops and interviews could be held in order to collect ideas and comments.

Step 4: Select and develop assessment tools of climate change

- The tools needed for climate change impact assessment including quantitative and qualitative methods to determine the impacts of climate change, risks and damage caused by the impact of climate change, the adaptability and the vulnerability of the sectors and of the community. These tools consist of an Assessment Matrix, Vulnerability Map, Mathematical model, etc. **Appendix A** introduces a number of tools for climate change impact assessment for several representative sectors such as water resources, agriculture, health, transportation and urban management.
- **Assessment matrix** is a popular and effective tool for for climate change and sea level rise impact and vulnerability assessment. The details of assessment matrix methods are presented in Category A1 of **Appendix A**.
- Within the condition of assessing the impact of climate change at the provincial level, we should select the available tools, or models, rather than developing the new ones. The working group, which is responsible for assessment, should refer to available research and consult with specialists, research institutes, consulting firms and other international organizations to gain experience and inherit successful results and models as a basis for selecting appropriate assessment tools.
- **Criteria for selection of assessment tools** are:
  - Meet the proposed objective of the impact assessment
  - Produce results with appropriate accuracy
  - Fit the capacity and the allowed time of locality.
- Besides that, when considering the choice of tools and models, it also needs to consider the input data of these tools and models. If data is not sufficient or poor, the error in assessment results will be very high even if the model is perfect. The main factors proposed when considering the input data for the model are: what are the demands for information and data? Is existing data

and information enough to run the model? Is it necessary to collect more data? Is there enough time and resources to collect the necessary data?

- The necessary information and data for assessing the impact of climate change are numerous and collected from different sources (see **Table 3.2**).

Step 5: Assess the impact of climate change, sea level rise according to the scenarios

- Assessing the impact of climate change and the vulnerability due to climate change should be applied for the present and future (according to the timeframe determined in **Step 3**).

Table 3. 2. Information and data needed for climate change impact assessment

Climate change and sea level rise scenarios, results of hydrological and hydraulic models
Hydrology data, statistics on natural hazards and the damage in the past
The final report on the status of the population, migration, income, budget, social services, public works, infrastructure, poverty, access rate to clean water, electricity and social services, etc. in the statistical reports
Data on economy, society, education and environment
Plans, the socio-economic development plan, sector development plan, urban development plan
Important projects, programs that have been or will be implemented in the city/province, including projects related to the environment, disaster risk management and climate change proofing
Local development policies and strategies
The research related to climate change, disaster proofing and risk management that has been implemented in the area
The experience of assessment on the impact and the vulnerability due to climate change

- The content of climate change impact assessment includes: assessing the impact on the natural environment and assessing the impact on the socio-economy. The proposed content for the assessment is listed in **Table 3.3**.

*Please refer to **Appendix A** for more details of climate change impact assessment by sector.*

- Assess the impact of climate change in the present shall be as follows:
  - Develop an Impact Assessment Matrix, which describes the threat posed by climate change according to the scenarios and assess the affected objects. For example, **Table 3.4** describes the assessment matrix of climate change impact on infrastructure and **Table 3.5** describes the Assessment Matrix of climate change Impact on the priority groups.
  - Using investigation methods, interviews, consultation workshops, or other assessment methods (see **Appendix A**) determine the impact of climate change on the objects and fill the results in the corresponding cells of the Assessment Matrix (See Tables 3.4 and 3.5): *What kind of the factors and their impacts which are needed to be determined? What is the likely level of the impact? Where does the impact occur, in which area?* For example, in order to assess the impact of flooding to infrastructure, hydrological models should be used (e.g. NAM and MIKE11[3]) to assess how much flooding in the region, time of flooding, the characteristics of each type of infrastructure, etc. on that basis, the specific level of the impact could be issued.
- For ***impact assessment and vulnerability in the future due to climate change***, we need to consider to a combination of climate change and development scenarios. This approach is the development and scenario analysis method.
- ***Development and scenario analysis method*** is a method which considers the impact and vulnerability of different combinations of climate change and development scenarios. To simplify and ensure that the assessment is diverse and adequate, a combination of three climate change scenarios and three development scenarios are normally used –meaning that there are 9 cases for assessment: The climate change scenario 1 corresponding to the development scenario 1 (case 1), corresponding to the development scenario 2 (case 2), corresponding to the development scenario 3 (case 3), etc. However, depending on the capabilities and requirements of each locality, we can also select a fewer number of cases for assessment. For example, three climate change scenarios combined with two development scenarios (6 cases) or one development scenario (3 cases). An example of this combination is shown in **Figure 3.3**.

[3] **MIKE 11** is a computer program that simulates flow and water level, water quality and sediment transport in rivers, flood plains, irrigation canals, reservoirs and other inland water bodies. MIKE 11 is a 1 dimensional river model. It was developed by DHI , Denmark

- After determining the combination of scenarios, an impact assessment of climate change for sectors and groups according to each combination of scenarios is conducted, the results of the process are noted into an Impact Assessment Matrix.

Step 6: Assess the risks due to the impacts of climate change and sea level rise

- Risk assessment assesses the potential damage caused by climate change to different sectors and social groups.
- Risk is determined based on the damage levels to the environment, economy, society (consequences) of the impact and the likelihood of that impact. There are various quantitative and qualitative methods which can be used to determine the risks:
  - ***Quantitative:*** The economic models were developed and implemented by economic professionals.
  - ***Qualitative:*** **Table 3.6** introduces a risk measurement method according to qualitative scales of damage and probability of occurrence. The scale of damage has five levels: Negligible, Medium, Important, Serious and Disaster. The scale of probability of occurrence has five levels: Hardly, Unlikely, Likely, Very likely and almost surely. Depending on the combination level of damage and probability of occurrence, the risk might range from “Low" to "Very High". For the risk assessment at the community-level, the scale of measurement will be simplified by 2 or 3 levels.
- The working group collects ideas of risk assessment from stakeholders (or the results obtained from the model) and records the results into the Assessment Matrix, for example, **Table 3.4** and **3.5**.

Step 7: Assess the adaptability and vulnerability

- Adaptability assessment is used to review the plans, reality and current adaptive schemes of the assessed objects and whether or not they have the ability to adapt to the risks due to climate change.
- To assess the adaptation capacity, the parties discuss and assess according to the qualitative scale (this may include 3 levels: low, medium, high – see **Table 3.6**). Questions to guide the discussion evaluation are: *Were there any plans to respond to the effects that had been forecasted? If yes, which plans? Who carries these out? Where? Is it effective? Is it adaptive enough according to the assessment?*

Table 3. 3.Content of impact assessment of climate change and sea level rise

➢ **Assess the impact on the natural environment**
- **Land**
+ Salinity intrusion
+ Flooding
+ Landslide
- **Water**
+ Rainfall
+ River flows
+ Surface water
+ Groundwater
+ Potential evaporation
+ Flood
+ Drought
+ Salinity intrusion
+ Tides
- **Air**
- **Ecosystems and biodiversity**
+ Terrestrial ecosystem
+ The intertidal ecosystem
+ The aquatic ecosystem
+ Other ecosystems
- **Marine**
➢ **Assess the impacts on the economy**
- Agriculture
- Forestry
- Fisheries and aquaculture

- Energy
- Industry
- Transport
- Construction
- Tourism

- **Assess the impacts on society**

- Migration
- Social security
- Conservation of cultural heritage, history
- Conservation of customs, etc.

Table 3.4. Example of an assessment matrix, risk and vulnerability for infrastructure sector

Object	**Disasters caused by climate change according to scenario**							
Affected sector	Typhoon (increase intensity and frequency)				Sea level rise			
	Effect	Risk	Adaptability	Vulnerability	Effect	Risk	Adaptability	Vulnerability
Roads								
Railway								
Aviation								
Drainage system								
Water supply system								
Energy infrastructure								
Public works								
…								

Table 3.5. Example of an Impact Assessment Matrix, risk and vulnerability for social groups

Object	**Disasters caused by climate change according to different scenarios**							
Affected sector	Temperature (heat-wave which temperature is above 35^{o}C)				Flood (increase intensity and frequency)			
	Effect	Risk	Adaption ability	Vulnerability	Effect	Risk	Adaption ability	Vulnerability
Elderly								
Women								

Children	
Farmer	
Fishermen	
Immigrants	
Minorities	
…	

Figure 3.3. Example of combinations between climate change scenarios and development scenarios

Climate change scenario 1 + Development scenario 1	Climate change scenario 2 + Development scenario 1	Climate change scenario 3 + Development scenario 1
Climate change scenario 1 + Development scenario 2	Climate change scenario 2 + Development scenario 2	Climate change scenario 3 + Development scenario 2
6 evaluation cases based on 3 Climate change scenarios and 2 Development scenarios		

Table 3.6. Qualitative scales to determine risk caused by climate change

Probability	**Loss - Damage**				
	Negligible	**Medium**	**Important**	**Serious**	**Disaster**
Hardly	Low	Low	Low	Low	Low
Unlikely	Low	Low	Medium	Medium	Medium
Likely	Low	Medium	Medium	High	High
Very likely	Low	Medium	High	High	Very high
Almost Surely	Low	Medium	High	Very high	Very high

Table 3. 7. Qualitative scales to determine vulnerability by climate change

Level of risk	Adaptation capacity		
	Low	**Medium**	**High**
Very high	High	High	Medium
High	High	Medium	Medium
Medium	Medium	Medium	Low
Low	Low	Low	Low

- Vulnerability is determined from the level of risks due to the impacts of climate change and adaptation capacity. If risk is low and adaptation capacity is high, the vulnerability is low. Conversely, if risk is high and adaptation capacity is low, vulnerability is high.
- An assessment of vulnerability, similar to risk assessment, is also collected through consultation with participants (or the results obtained from models) and the results are recorded in the evaluation matrix. A qualitative measurement scale as in **Table 3.7,** can be used to evaluate the possibility of vulnerability caused by climate change.
- Vulnerable areas can be displayed through the maps called a vulnerability map.
- When conducting an adaptation and vulnerability assessment, we should pay particular attention to the special cases and the uncertainty of the scenarios through a *Sensitivity analysis* and *Threshold analysis:*
    - ***Sensitivity analysis*** is the analysis of vulnerability changes of the object that is being considered when we change the magnitude of the climate change parameters. If the variation in parameters causes great change in vulnerability, it means that the object is considered to be very sensitive to climate change parameters. We need to prepare a series of appropriate solutions for that object.
    - ***Threshold analysis*** is an analysis to determine the threshold of climate change at which beyond the resistance of the studied object. For example, if the temperature is above 35°C and lasts continuously for four days, shrimp will die, or if the flood water level is maintained at 50cm for over 7 days, the road system in certain areas will be damaged.

Note:

- The consideration of all relevant factors in the assessment process is an impossible task. Therefore, evaluation should indicate what factors are taken into account, what have not been taken into account, why? And the effects of not taking into account these factors, etc.
- Results of impact assessment, risk, and vulnerability will be used to:
    - Describe the characteristics and level of risk;
    - Identify the needs and time to adapt;
    - Describe the nature of the adaptation methods.

Chapter 4. Identification of adaptation solutions for climate change

4.1. Approach

The goal of adaptation is to improve adaptation capacity and reduce vulnerability caused by climate change and to maintain the local socio-economic progress towards sustainable development.

The adaptation plan therefore offers solutions to improve the adaptation capacity of a community and their economic activities according to three orientations as follows:

- Provision: Solutions in order to prepare to respond to the risks of climate change;
- Protection: Solutions to avoid the predicted risk of climate change and protect the status quo;
- Resistance creation: the adaptation solutions to increase a resistance towards to damage by climate change.

Adaptation solutions can be classified according to methods of implementation measures:

- Capacity building solutions: Increase cognitive, social capacity, institutional capacity;
- Adjusting solutions: Intervene or adjust plans, or policies which are being implemented;
- Technological solutions: Provide new technologies and designs;
- Mechanism solutions: Develop guidelines, criteria and new procedures;
- Infrastructure investment solutions: Re-housing and provide water supply and drainage system, dike system;
- Ecological solutions: Conserve and improve the natural environment, implement restoration and reforestation;
- Economic solutions: Diversify or support livelihoods.

When identifying adaptation solutions, we should take into account the uncertainty of climate change and development scenarios. It means that people select solutions, which would always aim to enhance their adaptation ability even if climate change did not happen, these are the so called ‘co-benefits solutions’.

Gender equality and poverty eradication issues should be integrated into the identification process of appropriate adaptation solutions.

Normally, the effective adaptation solutions are more or less based on initiatives and local experience.

4.2. Identification and selection of adaptation solutions process

The identification of adaptation solutions is undertaken when the results of climate change impact assessment are available (see Figure 3.1). The assessment results (including potential impacts, the level of risks caused by the impacts, the adaptation capability of the objects to the risks and the vulnerability of objects) are part of the input information for the identification of adaptation solutions. Other input information include: objectives and proposed requirements for the adaptation solutions, the available solutions, resources and limitations.

Objectives, requirements, resources and limitations in the process of identification and selection of adaptation solutions are determined with the involvement of stakeholders including government, community organisations, businesses, donors and beneficiaries.

The identification and selection of adaptation solutions can be seen in Figure 4.1 below.

Step 1: Determine the need of adaptation

- Adaptation need determination is to find if it is necessary to have adaptation solutions. This should address: Where? How long is the adaptation time frame?
- Adaptation need determination is undertaken by analyzing the assessment results and vulnerability (a vulnerability matrix). The adaptation solutions should be developed for the groups which are highly vulnerable due to climate change impacts.
- The results of the climate change impact assessment may show that there is no need to adapt (or no need to supplement adaptation measures). This case occurs when a community has good adaptation capability, or when the local people, autohries and community organisations are interested in short-term and urgent objectives rather than climate change issues, or even when the stakeholders are not fully aware about the dangers of climate change.

Step 2: Identify selection criteria for adaptation solutions

- To ensure that adaptation solutions achieve the desired results, as well as have the consensus from the participants and beneficiaries, the selection criteria for adaptation solutions must be determined at the beginning with the participation of stakeholders including authorities, donors and beneficiaries.

- The criteria for adaptation solutions include technical and economic criteria such as the available solutions (availability), reasonable expenses (costs), effectiveness, efficiency and feasibility.
- Moreover, in order to take into account the uncertainty of the climate change scenarios and the attachment of adaptation activities to local development plans, it‘s necessary to consider the criteria which are more strategic, such as:
    - Synergies: The proposed solutions are linked to other projects, plans and specifications, planning and development policies and do not interfere or conflict with the existing programs or plans;
    - Multi objective: The same solution but this achieves multiple adaptation objectives at the same time;
    - Flexibility: Solutions which are easy to adjust and modify as needed or when there are any changes;
    - Learning: other activities in other places can be references for the proposed solutions and the proposed solution should be able to scale up.
    - Political and social acceptance: There is opportunity to perform the solution;
    - No regret: The effect of solution would be positive for all climate change scenarios even if there were no climate change.
- In general, there are many criteria to select adaptation solutions, depending on priorities, strategy, local orientation and the responsibilities sharing of the parties involved.

Figure 4. 1. The process of identifying adaptation solutions for climate change

Step 1: Determine adaptation need
Step 2: Identify selection criteria for adaptation solutions
Step 3: Recommend adaptation solutions
Step 4: Evaluate and select priority adaptation solutions

Step 3: Recommend adaptation solutions

Based on the adaptation need (the result of Step 1) and the selection criteria (Step 2), the local working group may suggest some preliminary solutions *(Refer to the representative adaptation solutions for some regions and sectors, presented in Appendix B).*

Presentation of information on proposed adaptation solutions: The required information includes characteristics of corresponding solutions to the proposed adaptation target which meet the selection criteria. The information can be presented in the form of matrices or tables as a basis for the evaluation of the selection of a solution (s) (see **Table 4.1**).

Table 4. 1. Description of adaptation measures

No.	Measures	Objectives				Criteria				
		Environment	Economy	Sociality	Others	Connection	Flexibility	Participation	No regrets	Others
1	Measure									
2	Measure									

Step 4: Evaluate and select priority adaptation solutions

There are many methods to identify and evaluate adaptation solutions. This guide will show two methods, which are the most common and simplest, called the **cost-benefit analysis method** and the **multi-objective matrix analysis method**.

1. Cost-benefit analysis

The cost-benefit analysis is one of the basic tools to evaluate the economic effectiveness of intervention activities or investments. In the case of applying adaptation solutions for climate change, the method provides information on costs and benefits of adaptation solutions that are proposed as the basis for the comparison of those solutions. These costs and benefits sometimes cannot be measured by currency but will be "estimated" by the stakeholders.

The cost of adaptation solutions includes:

- Direct costs such as implementation costs, operation costs and maintenance costs during the implementation of the solutions;
- The incidental costs in the future will be discounted by a certain percentage annually, known as the discount rate;
- The other costs. These costs can be classified such as social and environmental costs and should be taken into account during the evaluation process of climate change adaptation solutions.

The benefits of adaptation solutions are measured by damage and loss, which are prevented, (e.g. infrastructure and livelihoods are protected). It also includes social and environmental benefits.

Normally, when the ratio of the cost-benefit smaller than 1 (the costs outweigh the benefits) the solutions are not effective.

- For important and large-scale solutions (e.g, the construction of a dike or dam), it's necessary to perform strictly the assessment of macroeconomic and finance.

Analysis of costs and benefits can be qualitative, quantitative or semi-quantitative (some parts are quantitative analysis, others are qualitative analysis). A thorough quantitative analysis of cost-benefit requires a lot of data (which may not be available) and requires significant resources. A quantitative cost-benefit analysis also needs complex calculations, especially solutions and projects related to climate issues. The selection of analysis method depends on the requirements of the locality, the importance and scale of the solution, time, energy and resources. This guide only introduces the method of qualitative analysis because quantitative analysis often needs to be done by sectoral experts.

Steps to analyze cost-benefit

Step 1: List all adaptation solutions which have been proposed and screened.

Step 2: Determine the cost to implement solutions including the social and environment costs. **The results of the cost analysis should be described in detail rather than through numbers** and determined through a discussion with the groups involved in the evaluation process (and possibly related stakeholders. The costs and benefits for society and the environment should be considered carefully. These results will be compiled into a cost-benefit analysis matrix (see Table 4.2).

Step 3: Identify the benefits from the adaptation solutions (because the loss is prevented as well as the social and environmental benefits gained). These results also will be compiled in the cost-benefit analysis matrix too.

Step 4: Determine a score scale for the costs and benefits, which have been identified and assign scores to these costs and benefits. For example, a string of values from 1 to 10. Smaller values (the number) represent the lower costs and benefits. The larger values represent higher costs or benefits.

Step 5: Calculate the costs and benefits of each adaptation solution (scores) and after that identify interest rates and cost (benefit/cost). Results will be compiled in the cost-benefit analysis matrix.

Step 6: Compare adaptation solutions based on the results from step 5 (a solution which has a higher benefits/costs ratio is ranked higher - that means it would be able to increase adaptation capacity and it would be more effective).

Step 7: Organize group discussions with professionals and stakeholders on the preliminary results in order to review whether it matches with reality, which problem has not been considered or considered in an incomplete way. Results of such discussion play an important role in ranking priority solutions.

Table 4. 2. An example of a cost-benefit analysis matrix

Adaptation Solutions	Cost					Benefit					Benefit/Cost Ratio
	Economy	Society	Environment	Others	Total	Economy	Society	Environment	Others	Total	
1											
2											

2. Multi-objective matrix analysis method

The multi-objective matrix is a tool to select and screen adaptation solutions when the selection has to consider multiple criteria. This is especially useful in cases where the decision is made when the input data contains uncertainty.

The evaluation of the satisfaction of criteria should use a scoring method. The lower scores mean that the adaptation solutions have lower efficiency and vice versa. In general, the scoring of a criterion represents the level of its importance in the enhancement of adaptability of the vulnerable object. The scoring should be based on experts' opinions, the results of consultation of stakeholders, the research results and calculations.

The assessment criteria and the adaptation solutions (or plans) are arranged in a table (called a matrix) which consists of columns and rows. The columns show plans while the rows represent the criteria. The value at the intersection of column and row is value of the solution for each criterion. Value evaluation (efficiency) of a solution is the total value evaluation according to the criteria of the solution. The adaptation solution which has the greater total score is considered to be more effective (see Table 4.3).

Table 4. 3. Example of a multi-objective analysis matrix

	Criterion 1	Criterion 2	Criterion 3	Total score
1				
2				
3				

In some cases, technical feasibility is a criterion to select or not select a plan.

Steps to analyze a multi-objective matrix

Step 1: Determine the evaluation criteria.

Step 2: Fill the adaptation solutions in the top row of the matrix and the criteria in the left side column of the analysis matrix.

Step 3: Determine a scoring scale for adaptation solutions that correspond to each criterion. For example, using a scoring scale from 1 to 5, in which, score 1 is the worst and 5 is the best.

Step 4: Provide a score according to step 3 for each solution corresponding to each criterion. In some cases, the scoring may not follow the principles identified in step 2, (e.g. the solutions are new, or innovative or incredibly efficient).

Step 5: Calculate the total score of each solution and fill in the bottom row of the analysis matrix. This value represents the classification by score of each solution corresponding to the evaluation criterion.

Step 6: Organize group discussions with the experts and stakeholders on the preliminary results to review whether the results fit the reality or not, is there a problem that has not been considered or not fully considered? How does the scoring for each criterion influence the total score of solutions and priority order? Are there any criteria which have not been considered but are important for the locality? The results of this discussion will play an important role in deciding the priority order of solutions.

Conclusion

Climate change impact assessment and the identification of appropriate adaptation solutions are the most important stage in the planning process to adapt to climate change. In that sense, these guidelines aim to provide an important contribution to support the task of building action plans for climate change responses for provinces and cities within the framework of the National Target Program to Respond to Climate Change.

This guideline provides the approach, principles, procedures and steps to assess the impact of climate change and identify adaptation solutions for a locality as well as some basic methods such as scenario development and analysis, analysis of costs and benefits, etc. Besides, the Guide also introduces methods that can be used to assess the impact for specific sectors and areas, along with some examples.

However, due to limited time and resources this document is generally applicable for all the provinces and cities, it cannot describe in detail each specific methods. It only introduces the most basic methods, the most important steps and the most common principles and notes. It should be noted that, each locality has different assessment requirements, characteristics, natural conditions, economic and societal conditions and the available information sources are also different.

Besides that, there are some points to keep in mind when assessing the impact of climate change and identifying adaptation solutions:

- The support and commitment of the local government, implementation procedures, responsibilities, coordination and collaboration among stakeholders, information sharing, consultation and the participation of the local community are especially important in the planning process to respond to climate change.
- When assessing the impact and identifying the adaptation solutions, it should take into account the changes of climate change and development scenarios in the future. Climate change impact assessment for a sector not only needs knowledge of climate change but also a deep understanding in that issue, that sector as well as the geographic location and other characteristics of the area where the operation of that sector takes place.
- Identification of climate change impact assessment and adaptation solutions must be updated regualrly, if there is any additional information about the climate change scenario and significant changes in plans and orientation of local development.
- When assessing, we need to answer some important questions:

- How to assess? Who? Which agencies should participate in the assessment? What should be their level of involvement? At which stage?

- Who is the priority subject? Which sector? The geographical area?

- Evaluation scope (space and time)?

- Steps to evaluate and identify adaptation solutions? Content/action which needs assessment? Evaluation criteria?

- Appropriate assessment methods?

- How do the climatic factors impact on evaluation objects? Level of impact?

- The information needed for the evaluation? What is the kind of information that could be collected? How does the lack of information affect the assessment results?

- The impact of climate change on a locality? At what time? Area? Level? Which objects are the most vulnerable? Why?

- The adaptation solutions? The priority order of adaptation solutions? Why are these arranged in a certain order?

Finally, it is admitted that, although this guideline is a Technical Guideline, in order to be applied in practice, the users, especially the Climate Change Working Group and stakeholders involved in the assessment process of a locality need to be trained methodically, with direct support from experts.

Since this is a relatively new and difficult problem, this Guideline has inevitable shortcomings. The Institute of Meteorology, Hydrology and Environment, implementation team and project management Unit of CBCC, welcome any feedback from experts, other stakeholders and especially the comments based on practical experience so that we can revise and make this Guideline better.

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Appendices

Appendix A. Methods and tools to assess the impacts of climate change on sectors

A.1 Classification of climate change impact assessment methods

Impact assessment methods and the vulnerability of climate change include qualitative and quantitative methods. These methods can be divided into four main groups: empirical methods, extrapolation methods, methods of study of similar cases and expert methods.

A.1.1. Empirical methods

Empirical methods are commonly used in the medical, physics, chemistry, biology research. They are the standard methods to test assumptions or evaluate process, cause and effects by conducting experiments.

In assessing the impacts of climate change, empirical methods are used primarily to determine the impact of climatic and environmental factors (temperature, precipitation, salinity and flooding due to sea level rise, etc.) to the researched objects (e.g. crop yield, risk of disease, etc.).

Examples of the application of empirical methods in assessing the impact of climate change are as following:

- Studying the effects of climate, composition of the air on plants and seeds in laboratory for crops, perennial plant, pests and disease.

- Studying the effects of climate (temperature) and composition of the air (greenhouse gas) to the quality of water, food chain of the ecosystem.

- Studying the effects of climate on the characteristics of the soil, such as the degree of peat decomposition, activities of microorganisms, the washing of dissolved nutrients.

- Studying the effects of climate on the characteristics of construction materials, such as strength, thermal (related to energy efficiency).

Advantages: Empirical methods can provide information to test application of climate change effects prediction models on the natural environment.

Disadvantages: Empirical methods are only suitable for small-scale areas and targets, small scope of impact and the impacted environments which can be manageable.

A.1.2. Extrapolation of historical data methods

In this method, mathematical models are used to predict future impacts by extrapolating the observation data from the past. The use of mathematical models (also known as the simulation model) is done in four steps which are: selecting the appropriate model, checking data demand, developing and running the model and analyzing the results.

A.1.3. Analog case studies method

This method uses data from the analog cases in another area to assess the impact of climate change on the objects which are being considered.

There are four kinds of analog studies commonly used:

- analogical historical event,

- analogical historical trend,

- analogical current regional climate, and

- analogical regional climate in the future.

For example: Regional climates of An Giang, Can Tho, Soc Trang Province are analogical, historical trends of precipitation and annual average temperatures are also similar, so that the information related to the impact of climate change of those provinces can be used to refer to each other during the impact assessment process (Le Anh Tuan. 2009. "*Impact of climate change on ecosystems and agricultural development in the Mekong Delta", Forum "Biosphere reservation and sustainable rural development in the Mekong Delta* "5-6/6/2009).

A.1.4. Expert methods

This method gathers opinions and reviews of the experts on the impact of climate change on the objects which are being considered. The opinions and reviews by experts are gathered from the research materials, the assessment report or expert meetings.

For example: On 12/11/2010, the Steering Committee of Adaptation action to climate change of Agriculture and Rural Development Programme (hereinafter referred to as the Steering Committee for Climate Change) held a workshop to consult with the agencies that implemented the action to respond to climate change of Ministry of Agriculture and Rural Development in order to improve the action plan to respond to climate change of the sector during 2011-2015, with a vision to 2050. At this workshop, the opinions of the consultants and the relevant agencies were

exchanged and synthesized to supplement the draft of action plan. After this consultation, the Steering Committee for Climate Change has been continuing to consult the state management agencies and outside agencies for the early completed draft (Source: Ministry of Agriculture and Rural Development).

The above is a preliminary summary of impact assessment methods. This introduction is for reference only. The choice of any particular method depends on the locality and the characteristics of each case assessment and will be determined by the collaboration between local working groups and professionals.

In addition to the above methods, the impact assessment of climate change and vulnerability for the present time can also be done with the participation of communities and other local stakeholders.

A.2. Criteria and information used in the assessment of climate change in sectors

The criteria and information used to support the assessment of climate change impacts of some essential sectors are presented in **Table A1**, including the main effects, the impact assessment criteria, the possible risks, the adaptation capacity assessment criteria.

The content of this table is only for reference and not fully completed and only provide information for reference so users can quickly access during assessment process.

A.3. Methods and tools to assess the impact of climate change to water resources sector

In the field of water resources, the interested objects include:

- Storage volume of water sources: surface water and groundwater.

- Water quality: The change of chemical, biological, or the temperature of the water.

- Aquatic ecosystems - aquatic

- Water use demand (see **Table A2, A3, A4**).

Table A. 1. Criteria and information used in climate change impact assessment classifying by sectors

Sector	Major impacts of climate change	Criteria to assess the impact of climate change	Potential risks and damage	Criteria to assess the adaptation capacity
Agriculture and food security	▪ Temperature rise ▪ Sea level rise ▪ Storm and tropical depressions ▪ Flood, droughts, and other extreme events	▪ % of arable land in low land /dry areas ▪ % of agricultural productivity, annual variability ▪ Agricultural areas affected by storms, floods ▪ Some plants are difficult to adapt to climate change ▪ Proportion of people with access to safe food and water ▪ The amount of food reserved	▪ Agricultural productivity reduction ▪ Salt intrusion in land due to sea level rise ▪ Crop losses ▪ Many cultivars have degenerated leading to lower production ▪ Income reduction from agriculture ▪ Loss of access to food and clean water ▪ Not enough food reserved	▪ The state of dyke systems, irrigation structure and exploitation capacity, irrigation management ▪ Management capacities of agriculture and food reserves ▪ Research capacity and production of new varieties which have high adaptability ▪ Capability and management resources of natural disasters and the threats posed by climate ▪ Communication systems for farmers ▪ Social policies to support farmers
Fisheries and aquaculture	▪ Temperature rise ▪ Sea level rise ▪ Storms and	▪ % of land for aquaculture ▪ Fishery/fishing areas ▪ The nature and quality	▪ Losing lands for aquaculture ▪ Changes in fishery,	▪ The capacity of dyke systems and irrigation structures ▪ Management and research capacity of breeding production

Sector	Major impacts of climate change	Criteria to assess the impact of climate change	Potential risks and damage	Criteria to assess the adaptation capacity
	tropical depressions ▪ Flooding	of breeds ▪ Water quality of farming and fishing production	reduced farming and fishing capacity ▪ Damage to harvesting (farming and fishing) due to sea level rise or storm, flood ▪ The infrastructures of aquaculture are ruined ▪ Losses of lives and the means of fishing	▪ The capacity of the fishing fleet ▪ Forecasting capacity and early warning system for fishermen and aquacultural farmers ▪ The social policies to support fishermen ▪ Integrated management capacity for coastal zone
Industry	▪ Temperature rise ▪ Sea level rise ▪ Flood, storms	▪ Land for manufacturing ▪ Industrial structure: type of industry, the rate of the processing industry, high-tech, etc. ▪ The fuel sources for industry ▪ The value of industrial products	▪ Loss/reduction in the most suitable land for industry ▪ Changes in industrial structure ▪ Damage to machinery, factories, industrial infrastructure	▪ Dyke system, irrigation structures and urban infrastructure for industry ▪ Micro and macro policy management capacity in the industry sector and related fields ▪ Planning capacity of industry sector and material zone

Sector	Major impacts of climate change	Criteria to assess the impact of climate change	Potential risks and damage	Criteria to assess the adaptation capacity
		▪ The components of the cost of products ▪ State of manufacturing and labor efficiency ▪ The income and working environment of workers and labors ▪ Infrastructure of sector	▪ Labor productivity reduced ▪ Decline and depletion of raw materials for industrial production ▪ Reduction/loss of industrial revenue ▪ Increasing in price ▪ Unemployment and its consequences	
Transportation	▪ Temperature rise ▪ Sea level rise ▪ Storms and tropical depressions ▪ Flooding	▪ The infrastructure of transportation located in low-lying areas, coastal zone ▪ Transport demand ▪ Traffic jam and related parameters: flooding roads, digging roads ▪ The quality of construction and	▪ Damaging and destroying the infrastructure and means of transportation ▪ Hindering the traffic; causing traffic jams and damage to the price of transportation,	▪ The capacity of infrastructure in general: roads, bridges, drainage capability (infrastructure quality, the ability to design, construction) ▪ Traffic management capacity ▪ Financial capacity for transportation

Sector	Major impacts of climate change	Criteria to assess the impact of climate change	Potential risks and damage	Criteria to assess the adaptation capacity
		condition of the roads	waste of time and negative effects on the economy ▪ Causing accidents and harm to health, life and property	
Construction, infrastructure, urban/rural development	▪ Temperature rise ▪ Sea level rise ▪ Storms and tropical depressions ▪ Flooding and other extreme events	▪ The ratio of urbanization and the level of disparity between urban and rural ▪ The urban land and low-lying areas in the urban ▪ The problems of infrastructure: backward sewage, water supply, waste collection and treatment ▪ Lack of social	▪ Losing urban land and the tangible assets of urban/rural areas due to natural disasters ▪ The present problems will become more serious: Increasing flooding, contamination of the water supply system, increasing environmental pollution due to the	▪ General capacity of the irrigation system, drainage, dikes and other infrastructures ▪ State management capacity and management and development planning of urban/rural ▪ The design capacity, construction, supervision of construction, infrastructure, etc. ▪ Forecasting and warning capacity of the impacts of climate change ▪ Research capacity for appropriate adaptation measures

Sector	Major impacts of climate change	Criteria to assess the impact of climate change	Potential risks and damage	Criteria to assess the adaptation capacity
		infrastructure facilities: Schools, hospitals, public buildings, parks ▪ The level of development and investment in construction: housing, public works. The value of construction products ▪ Issues related to the supply of construction materials	interruption of collecting system, etc. ▪ Damage to houses, public buildings (damaged or destroyed), loss of shelters, disruption of education, health and community activities ▪ Damage to construction, reduce the value of products, increasing the cost of raw materials affecting the sustainable development of the market	
Environmen	▪ Temperature rise	▪ Indicators of	▪ Decline and	▪ Management, research and

Sector	Major impacts of climate change	Criteria to assess the impact of climate change	Potential risks and damage	Criteria to assess the adaptation capacity
t/ water resource/biodiversity	▪ Sea level rise ▪ Storms and tropical depressions ▪ Flooding and other extreme events	environment and natural resources: land, water, biodiversity, etc. ▪ The characteristics of the environment, natural resources and biodiversity of the assessed area ▪ Maps of vulnerable areas ▪ The condition of water pollution, urban air and vulnerability to disasters	depletion of the natural resources such as land, water, biodiversity ▪ Alteration of the natural ecosystem ▪ More severe problems of water and air pollution	forecasting capacity ▪ Financial capacity and effective use of financial sources for environmental purposes ▪ Infrastructure system, facilities, dykes, irrigation structures ▪ Capacity of propaganda, education and advocacy and the environmental protection awareness of the society
Health, public health and other social problems	▪ Temperature rise ▪ Sea level rise ▪ Storms and tropical depressions, flooding, drought	▪ Areas at risk of flooding due to sea level rise ▪ Infrastructure and medical equipment, accessibility to health care facilities ▪ Statistics and	▪ Increasing disease and losing life and damage to health ▪ Increasing social conflicts: poverty, unemployment, crime	▪ Management ability and early warning ▪ The capacity of the preventive health system and relief ▪ Social management capacity and crime prevention capacity. ▪ State and local policies on social

Sector	Major impacts of climate change	Criteria to assess the impact of climate change	Potential risks and damage	Criteria to assess the adaptation capacity
		evaluation of subjects with high vulnerability: the elderly, children, women, poor labourers, immigrants, drug addicts, prostitution and other crimes ▪ Education level of the society and the objects in vulnerable areas	▪ Interruption of social programs: education, health, etc.	issues: unemployment, poverty, social security ▪ Financial capacity and affordability to the society and the social security system
Services trade and tourism	▪ Sea level rise ▪ Storms and tropical depressions ▪ Flooding	▪ The area located in the low-land area, lower than sea levels ▪ Structure of the service sector, the sectors with high vulnerability such as coastal tourism	▪ Damage on properties and infrastructure ▪ Interrupting or destroying business causing financial losses	▪ Management, forecasting and warning capacity ▪ Resistance capacity of the infrastructure facilities, dykes and irrigation systems. ▪ The capacity to develop and implement the plan, development planning

Table A. 2. Methods to assess the impacts of climate change on water resources

Climate factors	Affected objects	Impact or risk	Assessment methods and tools
Increase of temperature	Water quality (surface water, groundwater, domestic water)	Increasing the risk of water pollution through changes in the characteristics of the layers of sediment, nutrients, organic carbon decomposition due to increase in temperature	▪ Vollenweider model to determine the maximum P, N content allowed ▪ Jorgensen model to calculate nutrient
		Increasing the risk of bogginess of reservoirs and toxic gases generation due to higher growth rate of algae	▪ - GIS map overlapping method to classify affected areas ▪ - Water quality assessment method based on WQI index ▪ - Classification (categorizing) method based on WQI
	Surface water and groundwater	Changing the intensity of the atmospheric circulation, water cycle, water regime, and other physical processes	▪ Mathematical model of the correlation among precipitation, temperature and flow rate for the basin
	Water demand for daily life and manufacturing	Water demand may rise while water reserve decreases	▪ - Conducting surveys for household and the production facilities and other objects; using statistical data from

Climate factors	Affected objects	Impact or risk	Assessment methods and tools
			water supply companies ▪ - Analyzing the forecast of water demand
Increase of Precipitation	Water reserves	Increasing water reserves	▪ - Hydrological models ▪ - Hydrological models ▪ - Models to forecast the changes of surface and ground water (see Table 2.13)
	Water quality	Water pollution can be spread due to heavy rain	▪ - The statistical models of public health ▪ - Developing flooding maps
Sea level rise	Water resources	Increasing the risk of flooding and soil erosion; the regime of flow and groundwater changed; geomorphology change in estuaries.	▪ - Forecasting model for surface and groundwater flow (see Table 2.13) ▪ - Forecasting model for sediment and geomorphology ▪ - Flood mapping method
	Water quality	Increasing salinity intrusion in rivers and groundwater sources	▪ - Forecasting model for salinity intrusion ▪ - Simulation model for the changes in riverine water quality (see Table 2.13)
		Water pollution due	▪ - The statistical

Climate factors	Affected objects	Impact or risk	Assessment methods and tools
		to widespread and prolonged flooding.	model for public health ▪ Flood mapping method ▪ Monitoring and evaluation method of water pollution
	Aquatic ecosystems	Salinity intrusion may damage to fresh aquatic ecosystem	▪ Experimental method ▪ Vulnerability mapping method
Increase in intensity and frequency of extreme events	Water resources	Increasing drought in some areas, while others are flooded.	▪ Map overlapping method ▪ Vulnerability mapping method
		Abnormal changes in river flow	▪ Model to forecast the changes in river flow
	Water quality	Low water level in lakes, ponds and river due to drought, leading to increased levels of pollution	▪ Water quality forecasting model (see Table 2.13)
		Increasing salinity intrusion due to drought	▪ Salinity intrusion forecasting models

Table A. 3. Models used to assess the impacts of climate change on water resources and water quality

No.	Forecast type	Model
1	Urban flooding forecast	Urban drainage model: SWMM, MIKE The hydraulic and hydrological model: NAM, MIKE 11
2	River flow changes	Hydrological model: SSARR, TANK, HECI, NAM, MIKE11
3	Sedimentation forecast	Sedimentation model
4	Forecasting the impact of climate change on hydrological regimes	Integrated hydrological model (Coupled atmosphere/ ocean/sea-ice general circulation models -AOGCM/GCM)
5	Soil erosion forecast	Erosion management model
6	Forecasting the changes of riverbed and estuaries	Sedimentation model: MIKE 21
7	Lake water quality changes	Lake water quality model
8	River water quality changes	River water quality model

Table A. 4. Example of climate change impact assessment on water resources in Ho Chi Minh City

Water supply: water shortage occurs in Ho Chi Minh City, especially in the **dry season. About 25% of population does not have access to tap water, although there were plans to increase water coverage to 100% of population by 2025.**
Ho Chi Minh City's drainage system: This system serves approximately 60% of the population and there are nine wastewater treatment plants in Ho Chi Minh City. The current wastewater treatment plants have the treatment capacity until 2010-2015 (Ministry of Construction, 2006). But due to lack of management and maintenance and it is generally in poor condition so Saigon River and Dong Nai

River, canal networks in Ho Chi Minh City and ground water are severely polluted.

Saigon and Dong Nai river as well as the entire network of rivers and canals in the city will be affected by climate change. Although the predicted total annual precipitation in 2050 will be as same as present level, but seasonal fluctuations in precipitation would be more severe. Precipitation will be higher with the presence of monsoon.

Flood Tides: Will affect the local water storage near Ho Chi Minh City. The operation and water management of the basin will be important when flood tides affects inland, in order to ensure a reasonable balance and to prevent the salinity intrusion while maintaining water supply and electricity generation. In the most extreme scenarios, it is estimated that the supply connections will need to be at minimum 1.5m above the ground to allow access if the planned flood control systems are not established.

Water treatment plants: mainly located near the river and the main canal therefore will be affected by flooding when water levels in the river and canal rise.

Surface water quality (rivers and canals): can be declined due to limitation of waste water treatment capacity and potential dispersal of exposed polluted water.

Source: Asian Development Bank (ADB) and ICEM - Center for International Environmental Management in collaboration with People's Committee of Ho Chi Minh City, 2009.

A.4. Methods and tools to assess the impacts of climate change on agriculture

Agriculture[4] is sensitive to climate factors such as temperature, sunny days, precipitation, etc. Therefore, climate change has strong impact on agriculture. The direct impacts include the impact on growth, crop yields, livestock, aquaculture, seasonal planting, and increase in pests, diseases affecting reproduction, growth of livestock, poultry, seafood, plants, reducing fishing capacity, causing damage to facilities, manufacturing facilities and fishing.

This Guideline introduces some typical methods to assess the impacts of climate change on cultivation (**Table A5**), breeding (**Table A6**) and aquaculture (**Table A7**). For cultivation, the objects are the crops, crop yields, harvest and farming land. For breeding, the objects are breeding area, species, infrastructure and breeding

[4] Agriculture here covers cultivation, breeding and aquaculture.

productivity. The objects of aquaculture are species, raising productivity, infrastructure, farming and fishing equipment and fishing productivity.

A.5. Methods and tools to assess the impacts of climate change on medicine service, public health

Climate change is not a new cause of disease or death, it just changes the factors that affect the health and life of humans and exacerbate morbidity and mortality (e.g. climate change makes extreme weather phenomena appear more intensely and more irregularly). When assessing the impact of climate change on health, we often do not consider clinical medicine (personal care) but focus on community health assessment (community care). The basic principle of public health is the precautionary principle in order to control the cause of disease, the risk to health and life. Adaptation to climate change by public health services includes the efforts to predict and plan the preparation to cope with the impacts of climate change on health and public health.

Climate change factors such as temperature, humidity and solar radiation can alter the concentration of air pollutants, causing cardiovascular disease, respiratory infections, etc. High temperatures will directly impact on the risk of illness and death, especially for those who are under stress or have mental health conditions. In addition to these direct impacts, climate change may alter water quality, dissolve toxics into the water environment (particularly high temperature promotes the "algae blooms") and through the food chain, the toxics will be accumulated in the human body. However, the assessment of these impacts requires intensive research for a long time, and therefore, is not included in the scope of the Guidelines (see Table A8).

This guideline introduces some methods to evaluate the impacts of climate change on some objects of public health and the medicine service sector include:

- Diseases related to temperature change: changes in temperature, heat wave (cold);
- Allergies;
- Infectious diseases;
- Diseases caused by air pollution;
- Human life;
- Infrastructure, medical equipment.

Table A. 5. Methods to assess the impacts of climate change on cultivation

Climate factors	Impacted objects	Impacts or risks	Assessment method
Temperature rise	Seed/crop	Changing local traditional crop plants, increasing tropical crops	▪ Surveys and Statistics ▪ Monitoring and evaluating the quality of the crop
	Productivity/ crop yields	Reducing crop productivity due to disease; water demand increases while the water source is limited due to drought	
Changes in the number of sunny days	Crop season	Changing the cropping season/harvesting season	
Increases in precipitation	Cultivated land	Flooding reduces the areas of cultivated land	▪ Developing flood maps

Climate factors	Impacted objects	Impacts or risks	Assessment method
		Risk of erosion, exhaust of agricultural land Increasing the area of salted land	▪ Monitoring and doing statistics ▪ - Using models to evaluate the salted intrusion level
	Seed/Crop	Impacting on the crop which is not hydrophilic due to increased and prolonged flooding. Increasing the conversion demand of plant varieties	▪ - Doing statistics and monitoring, experimenting
	Crop yields	Damaging and reducing productivity due to erratic heavy rainfall occurs in flowering time – harvesting time, or due to flooding	▪ - Statistics and quantifying the cost
		Productivity reduction due to soil and water are salted	
		Disease increase and pests affecting crop yields	
Other extreme events: storms, tropical depression	Productivity and breeding infrastructure	Causing severe damage to crops due to crop destruction, broken crops, etc. Destruct, damage to the infrastructure, breeding facilities, ponds, lakes, etc.	▪ Doing statistics and forecasting the damage

A.6. Methods and tools to assess the impacts of climate change on transportation and infrastructure

Infrastructure sector to be considered in this guideline includes: transportation, water supply, power supply and communications. Technical infrastructure plays an important role for the local development. The technical infrastructure networks make up a considerable area on the ground especially the communication network therefore they will be the impacted strongly by climate change. The drainage network, particularly the urban water supply, is one of the fields that need to be focused on.

This Technical Guideline focuses on two major sectors: transportation and water supply.

Transportation

Climate change will impact on transportation due to the changes of meteorological factors and extreme weather events such as heat waves, increased rainfall, storms and rising sea levels. These hazards will have different impacts on different types of transportation depending on the characteristics of the geography that traffic systems were constructed and operated.

In this guideline, the types of traffic (impacted objects) will be divided into 4 main groups:

- Road traffic
- Rail traffic
- Water navigation
- Air transportation.

The Guideline focuses only on methods of direct impact assessment. Indirect impacts such as increased social costs and environmental pollution will not be mentioned here due to its complexity and interdisciplinary nature (see **Table A.9**).

A.7. Methods and tools to assess the impacts of climate change on the water supply sector

For water supply and sewerage networks, there are two objects of interest: pipe and node constructions (collection stations, pumping stations, water treatment structures) (see **Table A.10**).

A.8. Methods and tools to assess the impacts of climate change on urban planning and development

Most urban systems are impacted by climate change. Some sectors are listed above such as: Communications, infrastructure and health. Therefore, this section focuses on the issue of land and land use planning and urban industry and services development.

Land and urban land-use planning

Climate change, particularly sea level rise will have serious impacts on land. This will affect the economic benefits associated with land use as well as affect the real estate market. Table **A.11, A.12** introduces a number of methods to assess the impact of climate change on land and land use planning.

Industry and Urban service development

Due to the impact of climate change, industry development and urban service will be primarily damaged economically. The impacted objects are industrial production and services (see **Table A.13**).

A.9. Methods and tools to assess the impacts of climate change on the energy sector

Climate change has strong impacts on the energy sector, in which the impacted objects include: energy demand, energy supply and the infrastructure of power supply network. In Vietnam, the basic energy source is electricity (hydro and thermal) and fuel - natural gas (see **Table A.14**).

Table A. 6. Methods and tools to assess the impacts of climate change on breeding field

Climate factors	Impacted objects	Impact and risk	Assessment methods
Temperature increase	Breed/or species	Impacts on the adaptability of livestock and changes the breeding habits	▪ Experimental studies of breed/variety and heat resistance capacity
	Breeding productivity	Increasing disease, causing great damage, reducing breeding productivity	

Climate factors	Impacted objects	Impact and risk	Assessment methods
Precipitation increase/sea level rise	Breeding land	Flooding reduces the breeding areas (barn, pasture, etc.)	▪ Flood mapping method
	Breed/ Species	Changing growth habit Increasing conversion demand for species/breed in case flooding occurs frequently and lasts long	▪ Observation and experimentation
	Breeding productivity	Reducing the food for livestock and livestock productivity	▪ Statistics and quantifying the cost
		Increasing disease in cattle, poultry, and the ability of disease spread	▪ Experiment and quantifying the cost
Increase of intensity and frequency of extreme events	Breeding productivity Breeding infrastructure	Storms and flooding cause significant damage to livestock, reducing the productivity and number of livestock Damaging or destroying breeding facilities	▪ Statistics and forecasting and quantifying the cost

Table A. 7. Methods and tools to assess the impacts of climate change on aquaculture

Climate factors	Impacted objects	Impact and risk,	Assessment method
Temperature increase	Species	Changing the distribution of habitats for specific species, especially the changes of	▪ Surveys and statistics

		structure and function of fish populations	
		Risk of losing ecosystems which are sensitive to temperature	
		Changing the availability of habitat due to the increase of main ocean currents	
	Culturing/fishing productivity	Changing environment of algae and other microorganisms affecting the nutrient level, reducing the productivity and quality of seafood Reducing productivity due to disease increases in high temperature conditions, aquatic species die in the prolonged heat wave.	▪ Statistics and quantifying the cost ▪ Assessing the impacts of temperature on the growth period of aquatic species
Precipitation increase	Species	Losing habitat due to changes in precipitation affect the volume of water (season or year)	▪ Surveys and statistics
	Culturing/fishing productivity	Changing the concentrations, particularly the salinity	▪ Surveys and field studies, water quality monitoring
		Losing or changing the location of the fish	
		Flooding, causing loss of seafood in ponds, lakes	
	Infrastructure, facilities	Lakes, ponds, marshes, canals for aquaculture are damaged Boats, fishing and culturing	

		equipment are damaged	
Sea level rise	Fisheries area	Salinity intrusion reduce the fresh aquaculture areas	
		Losing coastal wetlands and estuarine ecology due to changes in currents and sea level	
	Species	The invasion of other species leads to new competition or predation	
Other extreme events: storms, tropical depressions	Productivity and aquaculture infrastructure	Losing seafood in lakes, ponds, marshes Destructing, damaging to the infrastructure, losing or damaging to boats and other fishing equipments, etc.	▪ Statistics, assessment and damage forecast

Table A. 8. Methods to assess the impacts of climate change on health and public health

Climate factors	Impacted objects	Impacts and risks	Assessment methods
The changes of temperature and precipitation (sensitive parameters can be: The number of consecutive hot days with	Diseases related to temperature changes, for example: hyperthermia, hypothermia	Increasing the risks of disease, death due to prolonged heat/cold wave to those who work outdoors, the elderly, the patient, diabetics, people with cardiovascular problems, obesity, children and infants, the poor, the homeless. Illness will also be	▪ Meteorological modeling, "heat oasis" ▪ GIS ▪ Statistics

Climate factors	Impacted objects	Impacts and risks	Assessment methods
temperatures above 38^{o}C, flooding or no rain; the number of continuous rainy days, number of consecutive days without rain, the number of days with temperature lower than 10^{o}C, etc.)		exacerbated by stronger heat waves, less rain leading to drought, lacking of water.	
	Allergic diseases (allergic rhinitis, asthma, etc.)	Increasing allergic diseases due to increase of temperature and humidity, increase of ozone concentrations in the troposphere; especially in children, people with weak resistance	▪ Experimental methods
	Infectious diseases and epidemic diseases	Increase of temperature and humidity is favorable condition for mosquito development thus the increase can indirectly cause the increases of diseases such as malaria, dengue, especially in subjects with less resistance, such as children, the elderly, the patient, the poor, people living in low-income neighborhoods, poor sanitary conditions, people living in low-lying areas are at risk of flooding	▪ Experimental methods ▪ Surveys, investigation
		Increases in diseases caused by parasites	▪ Surveys, investigation

Climate factors	Impacted objects	Impacts and risks	Assessment methods
		Moving from areas affected by the insects and animals to higher latitudes with temperature changes	▪ Modeling, statistics, investigation, surveys
		Increasing and spreading infectious diseases through the contamination between human-human, animal-human such as flu	
		Increase in areas contaminated with the disease spread by water such as cholera (Vibrio Cholera), especially in areas where there is no access to clean water, low areas with high risk of flooding	
		Increases in diseases related to the digestive tract due to increase of temperature and humidity which is favorable conditions for the growth of molds, especially in the poor, people living in low-income areas, children	▪ Statistics, surveys
Changes of temperature and	Diseases related to air-pollution	Increasing risk of having respiratory tract infection, pneumonia, cardiovascular disease and	▪ Air quality monitoring, investigation, surveys,

Climate factors	Impacted objects	Impacts and risks	Assessment methods
precipitation		sudden death due to the increase of acid gases (NO_2, SO_2, etc.) and dust; especially children, outdoor workers, the elderly, people with heart and lung diseases	modeling
		Increase the risk of having cancer	▪ Investigation, surveys
Extreme events: storms, flooding, tropical depression	Human life	Increasing the risk of injuries or deaths due to the increase of intensity and frequency of storms, floods, tropical depression The most vulnerable subjects are elder people, children	▪ Statistics for damage, extrapolation (from historical data) ▪ Developing vulnerable map
	Infrastructure, medical equipments	Increasing the levels of damage to health infrastructure (hospitals, health centers, etc.) and medical equipments, relief	▪ Statistics for damage, extrapolation (from historical data) ▪ Flood maps

Table A. 9. The methods to assess the impacts of climate change on the transport sector

Climate factors	Impacted objects	Impact and risk		Assessment method
		Infrastructure	**Means of transport**	
Temperature increase	Road network	Change the time and progress of implementation (for example,	Increase the risk of damage and shorten the life of the components of the	Statistics and traffic surveys, risk

Climate factors	Impacted objects	Impact and risk		Assessment method
		Infrastructure	Means of transport	
		when the temperature is too high - above 40°C) Damaging and shortening the life of road (e.g. melting asphalt causes dilation, etc.)	vehicles such as: engine (overheating), tires, brakes, etc. Impact on health due to the amount of heat radiating from the highway, tunnel	assessment
	Railway	Rail deformation when the temperature is too high and maintained for a long time	There is potential bias of the signal on the tracks; increasing transportation time because the speed is reduced; increasing the risk of fuel leakage Damaging and shortening the life of trains and related equipments	
	Aviation	Infrastructure (factories, warranty stations) are impacted (damage, fire, etc.) when the temperature is too high	Need longer runways and more fuel because air density is decreased	
	Waterways	The minimum water level for	Increasing shipping costs by water	

Climate factors	Impacted objects	Impact and risk		Assessment method
		Infrastructure	**Means of transport**	
		operating conditions can be impacted	transportation Cause damage to the water transportation vehicles when the temperature is too high	
Precipitation increase	Road network	Increasing the depth, duration and intensity of flooding of coastal roads and roads in low-lying areas; tunnel flooding Increasing the level of destruction and damage to the road when floods occur more frequently and intensive, flooding time is prolonged	Increasing accidents on the road; transit services is disrupted; traffic congestion; causing accident damaging to health, life and property The road transportation vehicles are also more susceptible to damage in flood conditions.	▪ Statistics and surveys, traffic surveys, risk assessment ▪ Model: water balance, hydrology, hydraulics Thornthwaite, SWMM, MIKE11, etc. ▪ Flood mapping: ArcGIS, MapInfo, etc.
	Railway	Flooding railways Railways are at risk of being swept away and damaged	Risks to the safety of the equipment Ships and related equipment are in danger of being damaged and destroyed when floods occur intensively	

Climate factors	Impacted objects	Impact and risk		Assessment method
		Infrastructure	**Means of transport**	
	Waterways	Flooding harbors River beds can be changed (e.g. narrowed or eroded) in some parts, obstructing shipping activities	Causing damage to harbor facilities, increasing the risk of oil spills The vehicles, vessels can be damaged or destroyed when floods occur more frequently	
	Aviation	Flooding airport Overloading the drainage system		
Sea level rise	Road network, railways	Increasing flooding in the coastal roads and rail lines; tunnel /underground structures Eroding coastal roads Destroying and damaging the road, abutments, rails when high intensity storms occur	Traffic is obstructed Road and railways transportation vehicles are at risks of damages due to sea level rise which prolongs flooding time and increases the height of the waves when storms occur.	▪ Statistics and surveys ▪ Traffic survey ▪ Model: SLRRP
	Aviation	Extend the flooding time at the airport when flood occurs		

Climate factors	Impacted objects	Impact and risk		Assessment method
		Infrastructure	**Means of transport**	
		Overloading the airport drainage system		
	Waterways	Water level is deeper Causing damage to the harbor and wharf and related infrastructure due to prolonged flooding time.	Allow larger capacity ships	
Increase of intensity and frequency of tropical storms or typhoons	Road and bridge structures	Increasing the level of destruction and damage to road and railway infrastructure such as road, port, signal systems, lighting, factories, etc.	Roads, railways, airports, transportation systems, alarm systems are closed or disrupted Increasing risk of destruction, damage to the vehicles.	▪ Statistics and surveys ▪ Traffic Survey ▪ AOGCM, HURASI, SLOSH model

Table A. 10. The methods to assess the impacts of climate change on water supply and sewerage network

Climate factors	Affected objects	Risk/Impact	Assessment method
Temperature increase	Supply pipelines	Increasing the risk of thermal deformation, affecting the safety and water loss prevention	▪ Statistics, surveys, investigation, risk
	Water	Changing treatment solutions or	

Climate factors	Affected objects	Risk/Impact	Assessment method
	exploitation/ treatment facilities	increasing the treatment time because rising temperatures increase the amount of microorganisms and suspended matter in the water	assessment ▪ Develop flood maps
Precipitation increase/sea level rise	Water exploitation/ treatment facilities	Risk of flooding water supply and treatment factories	
		Interrupting underground water exploitation when flooding	
		Heavy rain accompanied by soil erosion in the upstream river affects process of surface water exploitation	
		Salinity intrusion prolongs the treatment time	
	Pipelines	Salinity intrusion and water supply pipelines corrosion increase the loss, leakage of water and increase the reverse osmosis ability that affects water quality	
		Heavy rain increases the amount of wastewater which causes overload to pipeline network	
		Flooding obstructs drainage, especially when the water level is higher than outlets.	
	Treatment facilities, pumping	Overloading the treatment constructions	
		Interrupting the processing system	

Climate factors	Affected objects	Risk/Impact	Assessment method
	stations	when there is a heavy rain or high tides	
		Requiring more investment in pump, embankments when the water level is higher than outlets' height.	

Table A. 11. The methods to assess the impact of climate change on land and urban land-use planning

Climate factors	Affected objects	Impact or risk	Assessment method
Changes in precipitation, sea level rise	The urban area	Loss of lands due to flooding, erosion Impacting/interrupting the economic activities, cultural and social activities, etc.	▪ GIS overlapping map method (see for example **in Table 2.22**), GDEM model, background altitude maps, geological survey profile
	The value of land and real estate market	Reducing the value of land in the flooded and landslide areas Reducing market liquidity Effecting the user rights and other fundamental rights of people associated with real estate	▪ Forecasting and assessing market, surveying

Climate factors	Affected objects	Impact or risk	Assessment method
	Developing land use planning	Causing difficulties in the development of urban land use planning due to the uncertainty of climate change, increasing natural disasters while land is limited and population is still increasing.	▪ Assessing and forecasting by the overlapping the vulnerability maps, calculating costs and benefits of different options
	Ability to implement plan	Delays in planning, poor execution	▪ Sociological forecasting and assessment

Table A. 12. Examples of assessing the impact of flooding due to climate change to urban land in Ho Chi Minh City by the map overlapping method

Objective: Based on the sea level rise scenarios developed for Ho Chi Minh City, the map overlapping method is used to identify flood areas affected by impacts of climate change in order to determine the scope and scale of the corresponding flooded urban land use to these scenarios.

Data:

Sea level rise scenario of the Ministry of Natural Resources and Environment (use medium scenario B2).

Scenario	Milestones				
	2020	2030	2050	2070	2100
Medium(B2)	12	17	30	46	75

Global terrain data: These are spatial data that are used to create three-dimensional maps and thus can draw a forecasted vulnerability map caused by

natural hazards such as forest fire and flood. There are two types of global terrain data which are SRTM and GDEM: (i) the SRTM data (Shuttle Radar Mission Topographies) are very detailed to draw the Earth's surface topography in three-dimensional space, is collected by interference method, allows the images from the dual antenna of the radar apart from the ground altitude; (ii) GDEM (Global Digital Elevation Model) is the data collected from sensors mounted on a satellite of NASA, which has detailed information about the average height of each region compared with sea level, the data has a resolution of 30m x 30m.

Local terrain data: These are issued by the Ministry of Natural Resources and Environment, including direct measurement points, which are shown in a digital map at a rate of 1:2000 and 1:5000. Topographic maps include points and contours which are digitized into a map layer as the points with longitude, latitude and altitude. The defective part from the actual measurement data is supplemented from SRTM data.

Methods:

This method is implemented on the basis of the city's GIS digital elevation map to determine the low-lying terrain with an elevation of less than 12cm, 17cm, 30cm, 46cm, 75cm, then areas identified that have potential to be flooded. Inland areas, the area blocked by the dykes and not connected to the sea or river will not be impacted by sea level rise.

Old value (cm)	New value (cm)
Less than 0	0
0 - 12	12
0 – 12	12
12 – 17	17
17 – 30	30
30 – 46	46
46 – 75	75
More than 75	No value

Therefore, areas should be selected according to the following criteria:

The topographic elevation is less than 12, 15, 30, 46, 75cm.

- Areas adjacent to the coast
- The areas connected simultaneously with the rivers, lakes and canals then connected to the sea.
- Counting the number of each resolution cell then multiplying by the area of each cell. The size of the resolution cell can be taken arbitrarily or taken directly to the original default size of the data.
- Calculating as a function of the coordinates of the vertices of the area, the area formula is built-in in geographic information systems programs; this method is calculated for vector data types (polygons).

Source: Le Van Anh (2010)

Table A. 13. The methods to assess the impacts of climate change on urban industry and services development

Climate factors	Impacted objects	Impact or risk		Assessment method
		Impact	**Risk**	
Temperature increase	Industrial production/ urban services	Impact on the working environment of workers	Reducing industrial productivity	▪ Temperature observation and survey, ▪ Sociological investigation
		Increasing the cost of cooling systems, air condition Machinery and equipment are at risks of damage,	Increasing production costs, increase the cost of services	▪ Statistics and Quantifying the value and cost
		Higher temperatures impacts considerably on	Number of travelers may decrease or increase depending on	▪ Surveys and statistics, comparison and evaluation

		services	regions Increase operating costs for tourism sector	
			Sales change (decrease or increase)	▪ Statistics and quantifying the costs
		Increasing water demand	Increasing costs	
Precipitation increase	Industrial production	Impact on raw materials	Reducing capacity and productivity Causing damage to properties Product price increases The risk of water pollution from the emissions of chemicals from plants when flooding occurs	▪ Statistics and quantifying the costs
		Impacts on the transport process, distribution of goods		
		The industrial infrastructures can be flooded for long periods		
	Urban services	Reducing outdoor entertainment activities	Revenues are decreased	

Sea level rise	Industrial Production	Factories, Industrial zones are flooded	Property is damaged	▪ Ground altitude surveys, GDEM models
			Decline in capacity and productivity	▪ Statistics and assessment
			Risk of spread of industrial wastes into the environment	▪ Ground altitude surveys, buried waste experiment
		Limited/narrow industrial land	Reducing investments for industry	▪ Decrease of industrial investment value
			Statistics and comparison, assessment	
	Urban services	Flooding the park, tourism areas	Property is damaged	▪ Ground altitude survey, GDEM flood model, quantifying the costs
		Reducing the business areas	Revenues are decreased	
			Investment costs increase	
		Disrupting transport and communication, reduce the number of tourists	Impacting the revenue from tourism	

Table A. 14. The methods to assess the impact of climate change on the energy sector

Climate factors	Impacted Objects	Impact, Risk		Assessment method
		Impact	Risk	
Temperature increase	Energy demand	Increasing demand for cooling, air condition	Increasing energy demand and energy costs	▪ Temperature observation and survey. ▪ Surveying the electricity demand
	Energy supply source	High temperature reduces the cooling performance of power plant	Increasing cost and reducing production performance	
	The facilities of the supply network	Conductor temperature rise	Reducing transmission capacity on power lines	▪ Calculate heat intensity of transmission lines
Precipitation increase	Energy demand	Many areas are flooded; Increasing energy demand for urban drainage pump	unable to meet the electricity demand for some areas	▪ Surveying the electricity demand
	Energy supply source	Increasing the water storage volume for hydropower	Favorable for power supply conditions while ensuring water	▪ Surveying and predicting precipitation volume

			reserve	
		Activities to provide energy are reduced due to floods	Affecting mining and gas drilling activities	▪ Surveying and predicting precipitation volume
		Thermal plants are flooded	Damaging properties	▪ Statistics and quantifying the costs
			Interrupting power supply operation	▪ Statistics and quantifying the cost, electricity transmission model
	The facilities of the supply network	Transmission network (lines, transformer stations are flooded)	Equipment damage, power supply is interrupted	▪ Statistics and quantifying the costs
			The risks of corrosion and damages to overhead lines	▪ Statistics and quantifying the costs
			Damages to underground lines	▪ Statistics and quantifying the costs
Sea level rise	Energy supply source	Exploitation infrastructure, rig are damaged	Property is damaged, Exploitation is interrupted	▪ Statistics and quantifying the costs
	The facilities of the	Gas pipelines are damaged	Supply interruption, gas losses	▪ Statistics and quantifying the costs

	supply network	Facilities	Flooded and damaged
		Underground lines	Corroded by salt water

Appendix B

Climate change adaptation measures

In order to be able to provide more information for the selection of climate change adaptation measures, this section introduces some typical adaptation measures which have been selected and used in climate change adaptation projects or programmes in Vietnam and other countries in the region.

Adaptation measures are considered based on 4 groups as follows:

- **Prevention**: The preparation and prevention solutions to respond to climate change and unusual events.
- **Protection**: the adaptation measures to protect the status quo, to avoid the predicted climate change impacts and to mitigate the damages.
- **Resistance creation**: the adaptation measures to increase the resistance to climate change impacts.
- **Readiness**: The adaptation measures to respond to the predicted climate change impacts.

Adaptation measures will be presented for some sectors such as water resources, agriculture, health, transportation and infrastructure, construction planning and urban design and energy. The solutions described here are incomplete and are used for reference only.

B.1. Adaptation measures in the water resources sector

(See Table B.1)

B.2. Adaptation measures in the agriculture sector

Although most of climate change adaptation solutions in the agricultural sector are often local, the planning of national adaptation strategies still plays an important role in promoting and supporting capabilities to apply the adaptation measures at the local level. According to the Intergovernmental Committee on Climate Change (IPCC, 1996), the important solutions at national scale include:

- Improve the quality of training and education for the people who depend on agriculture, especially who live in poor rural and isolated areas;
- Identify the vulnerability of the current agriculture system;
- Undetake study to establish new strategies and develop new plant varieties;
- Educate and communicate to bring research results to the farmers;

- Provide food programs, price support and other social security programs;
- Ensure transportation, distribution and market integration to provide the necessary infrastructure and food when the farmers have crop failures. At the local level, the best adaptation measures for agriculture should exploit what the weather conditions are and minimize the negative effects. Adaptation measures in the agricultural sector include adaptation measures for cultivation (A2), animal husbandry (4.3.2.2) and aquaculture (4.3.3.3).

Adaptation measures in cultivation

- The adaptation measures in cultivation have their own specific characteristics for each area, or region. Table B2 only shows general adaptation measures.

Adaptation measures in animal husbandry

- Adaptation measures in animal husbandry are mainly aimed at: consolidating the disease warning system; studies of technical solutions and technologies to improve breeding; changes in breeding methods in order to save land, energy and water. (see Table B3).

Table B. 1. Adaptation measures for the water resources sector

Climate factors	Impacts or risks	Adaptation measures
Temperature increase	Increasing the risk of water pollution through sediment layers, nutrients, or organic carbon decomposition	▪ Developing a regular monitoring and verification mechanism for water quality in ponds, rivers and streams
	Algae bloom leading to bogginess and the generation of toxic gases	
	Changing the intensity of the atmospheric circulation, water circulation and other geochemical cycles	▪ Developing monitoring regulations, master plan for water resources and constructing dam for water storage, keeping water balance
	Promoting the evaporation process, then increasing the concentration of pollutants in rivers, ponds or streams	

Climate factors	Impacts or risks	Adaptation measures
	Water needs increased due to the demands of beverages, cooling and air conditioning in daily life and for manufacturing	▪ Developing principles for water consumption; changing water use habits, propaganda to raise people's awareness of water use and water saving
	High temperatures in summer will cause difficulties for the provision of drinking water and for wastewater treatment	▪ Studying technologies and treatment methods, changing the operation principles, setting a flexible system to switch between groundwater and surface water
Precipitation increase	Increasing water resources and water reserves	▪ Developing a master plan for water resources, constructing water reserve systems
Sea level rise	Increasing the saline intrusion areas in the estuaries and groundwater	▪ Studies to develop dyke systems, salt dams; using artificial solutions: changing the location or altitude of water intake; lining the channel bottom ▪ Developing a salinity monitoring and analyzing system
	Fresh water becomes saline due to high tides	
	Impacting on fresh water resources at water basins	
	Saline intrusion may destroy the aquatic system in fresh water	
Increase in intensity and frequency of extreme events	Drought increases in some areas while in other areas flood is increased	▪ Developing master plan for water resources, building water storage systems; avoiding changes to the main flow in river when building dams; water
	Abnormal change in river flow	
	Water levels in ponds, lakes and	

Climate factors	Impacts or risks	Adaptation measures
	rivers are low while concentration of nutrients, suspended matter and salts are high leading to the changes in the taste and smell of water	storage ▪ Applying artificial solutions: changing the locations or altitude of water intake; Lining channels; Using closed channel instead of opened channels ▪ Combining all individual water reserve lakes into one system; use of artificial recharge method to reduce evaporation
	Increasing the salinity intrusion process due to drought	

Table B. 2. Adaptation measures for cultivation fields

Climate factors	Impacts and risks	Adaptation measures
Temperature change (increasing in summer, decreasing in winter)	Changing traditional crops in each region, increasing tropical plants areas	▪ Studies to find out the plants which have ability to adapt to changes of temperature and have higher resistance to disease
	Diseases have suitable conditions to develop in hot and humid conditions - and the development of diseases can reduce crop yields	
Changes in rainfall, sea level rise	Flood causes the loss of cultivated land	▪ Effectively using cultivated land, effectively usingraised bedson staging and hydroponic plantings, etc. ▪ Enhancing the effectiveness of cultivation planning
	Risk of erosion, fading in agricultural lands	
	Reducing productivity of crops which are not hydrophilic, increasing the	▪ Enhancing farmers' awareness of the

Climate factors	Impacts and risks	Adaptation measures
	demand for conversion of plant varieties	impact of climate change and adaptation measures ▪ Integrating climate change adaptation into plans, planning, and policies of agriculture sector ▪ Researching plant varieties which have high water and disease resistance and productivity ▪ Studying biotechnologies, fertilizers and flexible planting methods. ▪ Doing research on the seasonal transition of the plants which are vulnerable ▪ Developing social policies which support agriculture ▪ Building dyke systems, salt dams.
	Causing damage and loss of productivity due to unusually heavy rainfall during the flowering time	
	Heavy rains cause prolonged flooding and crop failures	
	Soil and water are intruded by salt, effecting on crops	
	Causing crop season changes, affecting food security	
	The increase of pests, pestilent insects cause negative impact on crop yields	

Table B. 3. Solutions to adapt to climate change in animal husbandry

Climate factors	Affected objects	Impacts and risks	Adaptation measures
Temperature changes	Genus-species	The increase of temperature affects the adaptation ability of livestock and changes their breeding habits	▪ Studying the application of biotechnologies in selecting genus and species which have high

Climate factors	Affected objects	Impacts and risks	Adaptation measures
	Breeding productivity	Increasing the risk of disease, causing great damages, reduce breeding productivity	disease resistance and high adaptability to extreme heat and cold conditions ▪ Strengthening measures to prevent and deal with diseases
Changes in precipitation/sea level rises	Breeding land	Flood causes the loss in breeding land	▪ Enhancing the efficiency of land use; applying new breeding technologies; limiting use of grazing methods ▪ Planning breeding areas which are less affected by climate disasters
		Increases in precipitation and sea level rise may reduce the grassland and grazing areas	
	Genus-species	Changing the growth habit	▪ Studying new technologies to select and make good breeds which have high adaptability
	Breeding productivity	Reducing area which provides food for livestock, then causing	▪ Study diversification of food for livestock

Climate factors	Affected objects	Impacts and risks	Adaptation measures
		productivity reduce	
		Increasing disease in cattle, poultry; increasing the ability to spread the disease	▪ There should be a bio-security system ▪ Actively preparing measures (on facilities, medicines, etc.) to respond to flood
Increase of intensity and frequency of extreme events	Breeding productivity	Storms and floods cause extensive damage to livestock, reducing productivity or the number of cattle	▪ There should be an efficient and timely early warning system to reduce the risk and damage to livestock

Table B. 4. Measures to adapt to climate change in aquaculture

Impacted objects	Impact and risk	Adaptation measures

Genus-species	Changing growth habit Changing habitat or living environment	▪ Studying biotechnologies to improve the breed and adaptability ▪ Studies to replace the fishing by fish culturing in the natural environment ▪ Studying fast growing varieties which have high disease resistance
	Natural seafood resources decline	▪ Propagating the policies to protect aquatic resources
Aqua culturing and fishing methods	Reducing the effectiveness of traditional fishing and culturing methods	▪ Studying the new technical solutions to support aquaculture to adapt to climate change ▪ Improving reservoir, reinforcing embankments and building dykes ▪ Increasing awareness and capacity (technical and machinery) for the fishing fleet ▪ Strengthening the storm warning system to provide necessary communication equipment for the fishing fleet

Adaptation measures in aquaculture

In aquaculture, strategies and solutions depend on physical, ecological and socio-economical conditions which include:

- The substance of climate change impacts on aquatic resources;
- The nature of aquaculture: in salt water, brackish or fresh water;
- Location of aqua resources;
- The types of aquaculture: in warm or cold water;
- Status of aquaculture;

- The type of business: trade or subsidies;
- The importance of aquaculture for the local, regional and national economy;
- The adaptation activities in other sector such as water resources, coastal resources, agriculture and land use.

Table B4 shows a number of typical adaptation measures for the objects: genus-species, fishing and culturing methods, the increase of productivity and effectiveness.

B.3. Adaptation measures in the public health and healthcare sector

To enhance the ability to adapt to the impacts of climate change in the healthcare sector, one of the priority things is to establish a public health surveillance system to detect changes in health related to climate change. This will form the basis to propose an action plan and to assess the effectiveness of adaptation measures. In addition, the provincial/city health offices need to be prepared and equipped with the ability to respond to the impacts when the extreme climatic events occur. This preparation includes the management, organization, skills, specialties, research, equipment, mobilization and raising awareness of the public (see **Table B5**).

B.4. Adaptation measures in the transportation and infrastructure sector

Transport

The groups of climate change adaptation measures in transport sector include: improving, adjusting the operation, monitoring and applying new technologies, sharing experiences, changing design, adjusting transport planning and land use planning as well as insurance (see Table B6)

Water supply (see Table B7)

B.5. Adaption measures in construction and urban development planning

Land and urban land-use planning

The macro solutions play an important role in enhancing the adaptive capacity in urban planning. Local stakeholders need to consider a number of factors, such as the height of ground, the active prevention solutions when the incidents occurred, the innovative design solutions, solutions to develop plans and manage post-planning, etc. (see Table B8)

Develop industries and services (See Table B9)

B.6. Adaptation measures in the energy sector

(See Table B10, B11)

B.7. Adaptation measures by region

In the scope of one region, the adaptation measures can be classified into four groups as followed:

- **The long-term planning measures**: urban planning, infrastructure system planning (transport, water supply-drainage systems), land use planning (agriculture zoning, tourism, nature reserves, etc.), base code planning;
- **Policy and economic measures**: The state and local policies of resettlement, land policy, compensation and clearance policy, tax and subsidy incentives policy;
- **Construction measures**: building the dyke-dam system, drainage system, houses on piles, construction materials solutions, building water reservoirs, etc.
- **Capacity building and awareness enhancement measures**: propaganda, mobilizing, educating to raise public awareness, especially in the health and disease hygienic sector, natural resources preservation and energy saving.
- **Technical measures for each sector**: Studies to adjust the species, seasonal changes and cultivation methods, culturing in agriculture, building material solutions, water treatment technologies.
- **Other management tools**: Monitoring mode, observing; early warning system; management information providing system.

To identify and select adaptation measures for a region, the measures for the sectors and different objects need to be general. In other words, these measures should cover different sectors such as institutional solutions, policies, technical solutions, construction solutions, socio-economic solutions, etc. Institutions and other stakeholders in the region should co-ordinate and work together. The measures for different objects need to supplement each other but should not overlap (for example, adaption measure for this sector should not be harmful to others). When the solutions for sectors meet the above criteria, the combination of these solutions will give us a package of measures to enhance the adaptation capacity for each region (see **Table B12**).

The selection of adaptation measures for region has to be based upon the local characteristics, the local context, the level of impact of climate change, the vulnerability level and also depend on the local ability to respond to climate change in different sectors.

Some examples of specific adaptation measures for each sector are presented in section 3.4. For specific regions, it is important to choose collective and general packages of measures.

Table B. 5. Adaptation measures in the health care and public health sector

Climate factors	Impacts and risks	Adaptation measures
Changes in temperature and precipitation **Extreme events: storm, flood, tropical depression**, etc.	Diseases related to changes in temperature, such as hyperthermia, hypothermia Increasing the risk of death due to prolonged hot/cold periods	▪ Using a standard health warning system ▪ Educating and communicate publicly, raising public awareness about the dangers from the change of temperature and heat wave/cold wave to minimize the disease related to temperature ▪ Applying the strategy of approaching highly risk objects ▪ Applying statistics and collecting information, building the database for public health and climate change ▪ Enhancing the processing capacity of the local healthcare system when natural disasters or epidemics occur ▪ Planting trees in urban areas to reduce the heat island phenomenon ▪ Designing projects that have heat shield technology
	Increase in allergies, rhinitis, asthma, etc.	▪ Raising public awareness on prevention and treatment in response to the increased risk of allergy causing agents
	The increase of diseases such as malaria, dengue fever due to increase in temperature and humidity which are favorable conditions for mosquito	▪ Set up a early disease warning prevention system for the community ▪ Updating and disseminating the information through the mass media ▪ Providing permanent medical services in sensitive areas

Climate factors	Impacts and risks	Adaptation measures
	development	
	The increase of diseases related to the digestion due to increase in temperature and humidity, which are favorable conditions for mold growth	▪ Develop and disseminate the guidance of signs and symptoms of the disease to the people through the mass media, flyers and preventive health care centers
	Increase in disease that are caused by parasites	▪ Educating and raising public awareness on environmental hygiene, destroying the abode of the parasites carrying the disease ▪ Providing permanent medical services at the sensitive areas
	Transition of disease affected areas (affected by diseases carriers and insects)	▪ Set a warning system by time for the community ▪ Updating and disseminating the information using mass media

Table B. 6. Adaptation measures in the transport sector

Climate factors	Impacts and risks		Adaptation measures
	Infrastructure	**Means of transport**	
Increase in temperature	Changing the progress and schedule of works (e.g. when the temperature	Increasing the risk of damage and shortening the life of the components of transport such as: the engine (excessive	▪ Adjusting the implementation time ▪ Adjusting the design and equipment for the means of

Climate factors	Impacts and risks		Adaptation measures
	Infrastructure	Means of transport	
	exceeds 40^{o}C)	heat), inner tubes, tires, brakes, etc.	transport to ensure they have good heat resistance (e.g. ventilation, cooling system)
	Causing damage and shortening the life of the road (e.g. melting asphalt, expansion)		▪ Change cooling system design ▪ Studying the application of heat resistant materials, new road construction technology ▪ Strengthening the maintenance
	Deforming the railway when the temperature is too high and prolonged	Potential error of the signals on the tracks; increasing operation time because of the speed reduced; increasing the risk of fuel leakages. Causing damage and shortening life of trains and related equipment	▪ Studying to apply new technologies, new design in rail construction ▪ Reducing traffic speed and frequency of some services when they are in high risk ▪ Improving risk warning system ▪ Checking and maintaining regularly
	Decrease in water level in channels	Increasing shipping costs Causing damage to the transportation means when the temperature	▪ Changing the transport direction, dredging channels and unclogging the flow

Climate factors	Impacts and risks		Adaptation measures
	Infrastructure	**Means of transport**	
		is too high	
Increase in rainfall	Increasing the depth, duration and intensity of flooding at the coasts and low-lying areas; inundating tunnels, railway lines and harbors Increasing the level of damage and cause damage to roads when floods occur more frequently, powerfully and longer Sweep away and damage railway lines	Increasing accidents, breaking off the transit service; traffic jams; accidents causing damage to health, life and property The means of transport are also more easily damaged during extreme flood conditions Damage to harbors, increasing the risk of oil spilling Ships, boats can be damaged or destroyed when extreme flood occurs more frequently	▪ Building sea dams and dykes ▪ Adjusting the current development planning for roads, waterways, railways and integrate climate change in the future plans ▪ Changing the design and materials ▪ Increasing the ground height of roads, rails ▪ Building the barriers to prevent flood for tunnels; installing backup pump system
Sea level rise	Increasing flooding along the coast, railway lines, tunnels/underground constructions Increasing the erosion of the road near the coast Destruction and destroying the roads, abutments,	blocking the traffic The transport on roads and rail are at risk of damage due to sea level rise, prolonging the flooding time and increasing the height of waves when storms occur	▪ Building sea dams and dykes ▪ Adjusting the current development planning for roads, waterways, railways and integrating climate change in the future plans ▪ Changing the design and

Climate factors	Impacts and risks		Adaptation measures
	Infrastructure	**Means of transport**	
	railways lines when intense storms occur Increasing the flooding time at airports when flooding occurs Overloading the drainage system at airports Causing harm to the ports and wharfs and related infrastructure because of long flooding time		materials ▪ Increasing the altitude of roads and related constructions ▪ Installing backup pump systems ▪ Enhancing maintenance ▪ Improving the drainage system
Increase in intensity and frequency of storm, tropical depressio n	Increasing the level of damage and destruction to the roads, rails, signal systems, lighting systems , factories, etc.	Closing or disrupting the roads, railways, airports and other transportation systems, alarm systems Increasing the risks, damages to the transport means	▪ Designing related works to respond to high wind speed ▪ Researching to apply new materials which resist extreme climate events ▪ Utilizing smart technologies to recognize unusual incidents

Table B. 7. Adaptation measures in the water supply-drainage sector

Climate factors	Impacted objects	Impacts and risks	Adaptation measures
Increase in temperature	The supply pipelines	Increasing the risk of thermal deformation, affecting safety and water loss prevention	▪ Establishing a monitoring system, checking the pipeline regularly ▪ Studies to apply new materials for pipeline ▪ Choosing underground solutions limiting pipelines contacting directly with the heat ▪ Studyies to apply new treatment technologies ▪ Proper planning of infrastructural altitude, preparing solutions to elevate the current altitudes of existing plants ▪ Studying water supply planning, flexibly switch groundwater
	Exploitation projects/ water treatment works	Necessary to change the treatment method or increasing the time due to the increase in temperature which can cause raising the concentration of microorganisms and suspended matter in the water	
Increase in rainfall/ sea level rise	Exploitation/ water treatment works	Increasing flooding risks for the water treatment and supply factories	
		Interrupting the underground-water exploitation when there is flooding	
		Heavy rainfall along with erosion at watershed areas will impact on surface water exploitation	
		It is time consuming for saltwater intrusion treatments	

Climate factors	Impacted objects	Impacts and risks	Adaptation measures
	Pipe works	Heavy rains increase the amount of wastewater, causing the overload of pipeline	and surface water, limit the impact of abnormal changes in surface water ▪ Planning the locations of water supply and pumping stations, the depth to take water to reduce impurities ▪ Planning the height of ground level ▪ Monitoring and checking the pipelines regularly ▪ There should be periodic maintenance mode for culverts, water supply pipelines ▪ Planning the ground level for new urban areas ▪ Fixing the outlets, location of pumping stations , treatment station
		Flooding hinders drainage, especially when flooding depth is higher than the height of water outlets	
	Pump stations, treatment stations	Overloading the treatment works	
		Interrupting the treatment works when there is heavy rains or high tides	
		Requiring the increase the investment on pumps, embankments when the flooding is higher than outlets	

Climate factors	Impacted objects	Impacts and risks	Adaptation measures
			reasonably ▪ Calculating appropriately the pipe size, using a separate sewer system ▪ Monitoring and a warning system in case of emergency ▪ Research treatment technologies which can respond to flooding conditions (lakes, outlets, pumping stations, etc.)

Table B. 8. Several climate change adaptation measures for land planning and the urban land use sector

Impacted objects	Major impacts	Adaptation measures
Urban land	Land lost due to flooding, erosion, depression Impacting/interrupting socio-economic activities, cultural activities, etc.	▪ Planning the heights of ground levels ▪ Ensuring the safety of flood corridors ▪ Avoiding planning in areas which have the risk of being submerged by sea level rise ▪ - Consider the overall impact of the planning area to neighboring areas

Impacted objects	Major impacts	Adaptation measures
Houses, public works, infrastructure	- The risk of losing houses - Damages to the property of people and state - Damages to urban population lives	▪ - Planning ground code ▪ - Engineering solutions (terrace, embankment, houses on piles, etc.) ▪ - Ensuring the technical factors (structural system, roof, wall, etc.)
Value of land and the real estate market	- Reducing the land value at the flooding/eroded areas - Reducing market liquidity - Affecting the user rights and the fundamental rights of people who associate with real estate	▪ - Rational land use planning ▪ - There is no population growth and urban development projects in flooded areas ▪ - Enhancing the management and supervision after planning ▪ - Enhancing the monitoring, supervision of the plan implementation

Table B. 9. Adaptation measures in industry and the service sector

Objects	Impacts	Risks	Adaptation measures
Industrial manufacture/urban services	Impacts on the working environment of employees	Industrial productivity decreases	▪ Improving the working environment of employees ▪ Utilizing new materials to reduce heat and to save energy ▪ Designing works to adapt to climate change ▪ Increasing
	Increasing the cost for cooling systems, air conditioning	production costs increase, the increase of the cost of services	
	Temperature and rainfall changes, storm and floods occur more	Reducing the number of tourists, increasing the	

	frequently, impacting on services	operating costs for tourism	green areas
	Increase of water demand	Sales turnover decreases	
Industrial manufacture	Impacts on raw material sources	Impacts on productivity and capacity	
	Impacts on transportation, distribution		▪ Applying many different transport means, prepare backup plan
Industrial manufacture	Flooding factories and industrial zones	Property damage	▪ Developing a master plan for urban areas ▪ Planning at the ground level
		productivity and capacity decline	
		Risk of spreading industrial wastes into the environment	▪ Managing dumping sites for solid waste and other industrial wastewater treatment areas ▪ There should be solutions to prevent actively and treat abnormal impacts

	Limiting/reducing land for industrial development	Reducing the investment for industry	▪ Developing an urban master plan ▪ Planning ground level ▪ Assessing and evaluating the projects in the view of environment and climate change ▪ Focusing on natural assessmen, terrain conditions when developing projects ▪ Focusing on environmental impact assessment and environment strategy
		The decrease of the value of the industrial zone	
Urban services	Flooding parks and tourist areas	Property damage	
	Reducing business areas	Reduction of revenues	
		The increase of the investment fee	
	The halt of transport and communication	Impacts on the revenues of tourist services	▪ Combining with adaptation measures for transport sector

Table B. 10. Several adaptation measures in the energy sector

Objects	Impacts	Risks	Adaptation measures
Energy demand	Increasing cooling demand, air conditioning	Increase in energy demand and energy cost	▪ Engineering solutions, (roofs, top cover, etc). Green building solutions, energy saving ▪ Using local materials, which are able to adapt to the environment ▪ Solutions for efficient energy use, energy demand reduction ▪ Enhancing propaganda and education in energy saving
	Increasing water pumping demand for urban area due to flooding	Increase of electricity demand	
Energy supply	The Increase of temperature reduces the cooling performance of the power plants	Increase of the price and reduction of the productivity	▪ Applying technology measures to improve the performance of the plant ▪ Limiting the losses, reducing the cost of electricity ▪ There should be a national energy planning; water storage for hydropower
	Increase of the water volume for hydropower	Good for power supply if the water resource is reserved	
	Increase of numbers of storm, flood	Impacts on fuel exploitation and the platform	▪ Enhancing the early warning system
	Thermal power plants are flooded	Property damage	▪ Planning construction projects having grounds code which is high enough
		Interruption of the power supply	

Objects	Impacts	Risks	Adaptation measures
			to avoid flooding
The facilities of the supply network	The rising in temperature of Conductors	Reducing transmission performance	▪ Studying the applications of new materials and technologies ▪ Ensuring the design and construction standards
	Transmission network (lines, substations) are flooded	Equipment damage, power supply interruption	
		Risks of corrosion and damage to overhead lines	
		Damage of underground lines	
	Constructions and facilities	Flooded and damaged	▪ Ground level planning ▪ Good planning for water supply network; ensuring technical quality standard; prevent leakage or loss
	Underground cables	Corrosion caused by salt water	
	Gas pipelines are at risk of damage	Interruption of gas supply, which can cause gas losses	

Table B. 11. Technical measures to adapt to climate change in the energy sector

Risks, Impacts	Measures	Type of measure	Adaptation capacity
Increase of energy cost for cooling	Standardizing the efficiency of air conditioners	Risk adjustment	▪ Increase in air condition efficiency would reduce the power cost even the initial capital cost would be

Risks, Impacts	Measures	Type of measure	Adaptation capacity
			higher ▪ Efficient regulations will help to reduce GHG emissions
Increase energy cost for cooling	Standardizing thermal cover layers	Risk adjustment	Increasing the isolation of roofs and reducing shading coefficient are solutions which have high economic efficiency ▪ Regulations will reduce GHG emissions
Flooding problems and heat diffusion in power plants	Policies on planning a power plant's location	Impact prevention	▪ The decision for construction of a power plant along a river bank should consider the potential flooding impact
Flooding and impacts of dangerous weather phenomena	Planning the location for coastal power plants	Impact prevention	▪ The permission for construction of coastal power plants and gas/oil factories should consider the impacts of sea level rise and dangerous weather phenomena

Risks, Impacts	Measures	Type of measure	Adaptation capacity
Decrease of electricity generation capacity of hydropower plants	Changing the approach of water resources and hydropower management	Loss sharing	▪ Decreases or changes of the flow regime and river morphology may require a change in the approach of water resources management (Nash and Gleick, 1993)
Changes in the power capacity requirements	Considering the demand and hydropower capacity	Risk adjustment	▪ Changes in electricity demand and hydropower production may require a change in design capacity
Increase of the cost of air cooling	Information program	Risk adjustment	▪ Government agencies can provide information about energy saving measures (e.g. product labeling program)
National electricity cost increase	Reducing energy subsidies	Risk sharing	▪ The electricity price subsidies deform the market and create wasteful consumption. Impacts on low-income groups

Risks, Impacts	Measures	Type of measure	Adaptation capacity
			can be improved through targeted programs

Table B. 12.Integrated adaptation measures for regions, localities

Adaptation measure	Specific measure	Related sectors	Special priority in region
Planning measures	Land use planning: Zoning agriculture and farming , tourism and nature conservation areas Rural areas	Agriculture sector; aquaculture sector; manufacturing industries; tourism	▪ Need to be considered in all regions as the long-term strategies to enhance adaptation capacity ▪ The sea and island areas need to be planned for conservation areas; planning and zoning the tourism areas, residential areas to avoid the areas which have high vulnerability due to sea level rise and extremes events ▪ Considering inter-regional factors for regional planning in order to ensure that the solution does not harm the

Adaptation measure	Specific measure	Related sectors	Special priority in region
			surrounding areas
	Infrastructure system planning: transport, water supply sources and drainage networks	Most of sectors, especially the transport and infrastructure sector, industry and manufacturing sector	▪ Special attention should be given to areas which have high flooding potential ▪ Plain regions and high lands should have plans for securing and properly using water resources
	Ground code planning for residential areas, factories and tourism	Urban development, industrial manufacturing, tourism	▪ Ground code planning should be given special attention in the coastal and urban areas ▪ Plain areas along the canal, low-lying areas should be given special attention to ground code and impacts of tides, sea level rise
	Sector planning (depend on each region)	Depending on each sector and locality	▪ Coastal areas and island should concern fisheries, agriculture, tourism, ▪ The plain regions should concern agriculture, health care and diseases ▪ Mountainous areas and plateaus should

Adaptation measure	Specific measure	Related sectors	Special priority in region
			pay attention to traffic issues, infrastructure, water supply, protection of forests and natural resources ▪ Urban area should focus on transport, infrastructure and base code
Construction measures	Building dyke systems and drainage system	Agriculture, fisheries, aquaculture, urban areas, residential areas, manufacturing areas	▪ Protection of agricultural land or urban land in the island and coastal, plain and urban regions
	Irrigation dams, reservoirs	Water sources, flood protection	▪ Rural areas with irrigations and the mountainous areas with dams, reservoirs
	Building house on piles, raising the ground Solutions of construction materials	Infrastructure construction, urban development	▪ Plain regions, areas along the canals ▪ Construction in urban and rural areas
Policy – economy measures	The policies of the state and locality about resettlement,	Responses in urban and rural development	▪ Most of the urban and rural areas should pay special attention to the

Adaptation measure	Specific measure	Related sectors	Special priority in region
	land policy, clearance, etc.		poor, minority ethnics
	Tax policy and incentive subsidy	Most of the manufacturing industry and services; in order to reduce vulnerability level for affected people	▪ Most of the regions and sectors
Education and social tools	Dissemination, education and raising awareness of the community, especially in the health and disease sector, in protection of natural resources, energy saving sector	Most of the sectors, especially in natural resources and the environment sector, education sector	▪ All urban and rural areas- paying special attention to poor and ethnic minorities
Technical measures for each sector	Studying the adjustment of species, seasonal changes and regimes in agriculture, technical measures of building materials, water treatment technology	Depending on each sector, focusing on agriculture, fisheries, industry	▪ Most of the regions and sectors
Other management tools	Monitoring and observation mechanisms; early	All sectors in order to adapt to rising sea	▪ Early warning of sea level rise in the sea, islands,

Adaptation measure	Specific measure	Related sectors	Special priority in region
	warning system; information management system	levels and other abnormal climate phenomena	rural and urban ▪ The information of planning and development in all localities