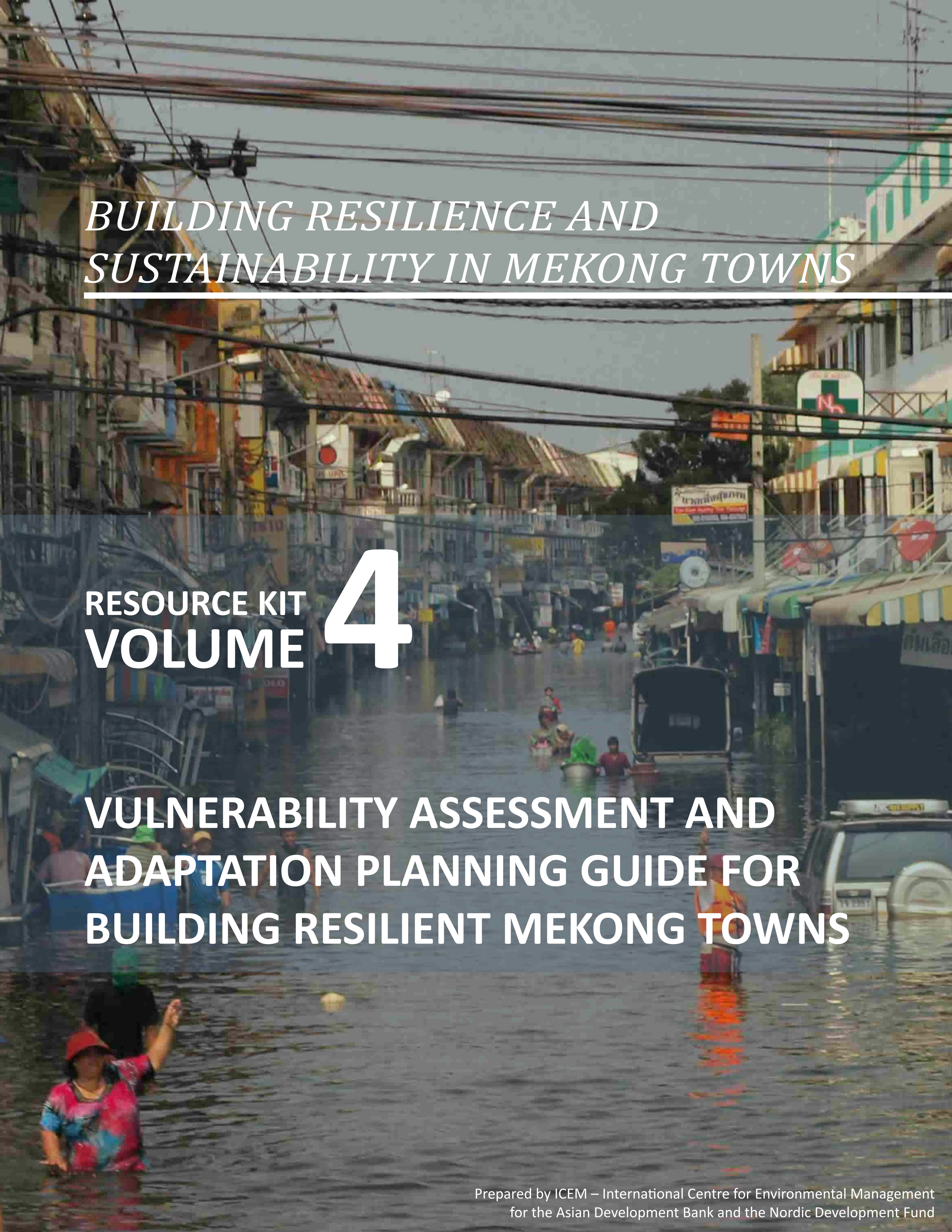

BUILDING RESILIENCE AND SUSTAINABILITY IN MEKONG TOWNS

RESOURCE KIT
VOLUME 4

VULNERABILITY ASSESSMENT AND ADAPTATION PLANNING GUIDE FOR BUILDING RESILIENT MEKONG TOWNS

Prepared by ICEM – International Centre for Environmental Management
for the Asian Development Bank and the Nordic Development Fund

Resource Kit for Building Resilience and Sustainability in Mekong Towns

This volume is one in a series of seven volumes that together comprise the Resource Kit for Building Resilience and Sustainability in Mekong Towns. The Resource Kit was developed with the Climate Change Core Groups from each town to promote nature based solutions and integrated green infrastructure approaches for building resilience in Mekong towns. Each volume can be used alone or as an integrated whole.

The seven volumes in the Resource Kit are (**this volume in bold**):

1. Nature Based Solutions for Sustainable and Resilient Mekong Towns;
2. Green Infrastructure for Building Resilient Mekong Towns;
3. Urban Planning for Building Resilient Mekong Towns;
4. **Vulnerability Assessment and Adaptation Planning Guide for Building Resilient Mekong Towns;**
5. Case Study 1: Building Urban Resilience in Battambang, Cambodia;
6. Case Study 2: Building Urban Resilience in Dong Ha, Vietnam;
7. Case Study 3: Building Urban Resilience in Kaysone Pomvihane, Lao PDR.

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MEKONG RESOURCE KIT PARTNER ORGANISATIONS

CAMBODIA

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LAO PDR

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INTERNATIONAL ORGANISATIONS

Nordic Development Fund (NDF), Asian Development Bank (ADB), ICEM - International Centre for Environmental Management, Swedish International Development Agency (Sida), United States Agency for International Development (USAID), German International Development Agency (GiZ).

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1. INTRODUCTION

This guide lays out a step-by-step process to assess vulnerabilities in your town and to plan and implement ways of adapting to those vulnerabilities. The goal is to increase resilience to climate change and other impacts.

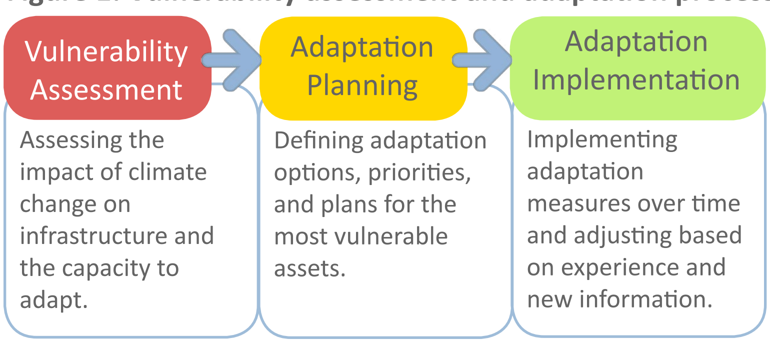
Whether you are working with smallholder farmers or sophisticated engineers, the process is the same. Though there is much to gain from going into the field, the process can also be completed by a single officer at a desk.

The guide includes templates that can be filled out in the office or in the field. Use as few or as many as necessary to get a clear picture. Once you have recorded the information in the templates, you can transfer the data to the relevant matrix to help with ranking and prioritisation. Your templates and data will also add legitimacy to your plans when dealing with decision-makers.

It is possible for a single person to complete the process outlined in the guide. However, if you are working with a team of practitioners, it is useful to consider including team members from a variety of technical backgrounds and stakeholder groups. The importance of coordination in planning, project design, and implementation increases as you move through the process, so there is value in creating a team with that coordination in mind.

It is also important to keep in mind that this guide includes two streams of activity: process and tools. The process includes each of the vulnerability assessment and adaptation steps from scoping through to implementation and replication. Tools are the activities you will use to gather the data and information necessary to complete each step. The number of tools you include will vary depending on the size of your target system and team. No matter how many tools you employ, the process will remain the same; you can use the steps as guideposts to keep you and your team on track.

Figure 1: Vulnerability assessment and adaptation process



Who will find this guide useful?

NOTES

Notes will appear in light blue boxes. Notes include experience, expertise, and advice that can help expand your understanding of the process.

TOOLS/METHODS/INPUTS

Tools/Methods/Inputs will be separated into blue boxes like this. The information in these boxes will help add depth to your process.

2. VULNERABILITY ASSESSMENT AND ADAPTATION STEPS

3. IMPACT AND VULNERABILITY ASSESSMENT

The impact and vulnerability assessment phase consists of five main steps. Each will help you understand and document the impacts of climate change threats and opportunities on existing and planned infrastructure (Figure 2).

Figure 2: The impact and vulnerability assessment process

1. Scoping	2. Baseline Assessment		3. Impact Assessment	4. Assessing Adaptive Capacity	5. Scoping Vulnerability
Assets	Baseline	Threats	Impact Assessment	Capacity	Vulnerability
Defining the system and its components and the geographic area as the target for the assessment.	Documenting past and existing conditions, including climate variability and extreme events	Expressing climate change threats and opportunities in terms relevant to the target system, sector and area.	Assessing potential impacts of threats and opportunities on the system and area	Assessing capacity of management agencies and communities to respond and recover	Establishing the relative level of vulnerability based on impact and adaptive capacity

STEP 1. DETERMINING THE SCOPE AND TARGET INFRASTRUCTURE ASSETS

The first step in any planning process is to set the boundaries or scope of what is being assessed. No one organisation can address everything, so it is important to define boundaries to focus your resources and energy. Scoping can be done by one practitioner or by a team, and can be completed in the office. It is best that all stakeholders agree on the scope of the assessment otherwise misunderstandings can arise. Scoping tends to be an ongoing process. As you learn more through your vulnerability assessment and adaptation planning, or as more details come to light through your work on the project, you may find that you need to adjust your scope.

Scoping relates to a range of variables including:

The infrastructure asset or system under focus and its components – what asset or component(s) is to be assessed? eg an irrigation system is made up of many parts: the catchment, water intake, sediment trap, distribution canals or piping, pumping facilities, command area. Climate change will affect each of those components differently with implications for system effectiveness. All need to be included in the assessment.

The linked assets which influence the effective functioning of the target system – what other assets need to be covered as part of the target system? eg. a flood gate operation depends on the condition of the canal system leading to and away from it, on the condition of the dyke slopes in which the gate is embedded and on surrounding land uses. All those things would be impacted by climate change with knock-on effects on the gate.

The geographic area – What geographic boundary (s) should be defined for the assessment? A problem with infrastructure design and management is that it can be too narrowly focussed and not recognise that it is part of a wider system which can shape effectiveness of design and operation. For example, drainage culverts under roads can be washed out if their design is not sufficient for the catchment area, especially if the watershed is degraded or road embankments unstable.

The stakeholders to be involved – What line agencies and community groups need to take part in the assessment and adaptation planning? The assessment can be undertaken as an in-house activity or one that is inclusive of affected stakeholders, such as other line agencies and local residents. Ideally, stakeholders should be involved at various stages in the assessment through field meetings, public hearings and workshops. The scope for participation may depend on the budget and resources available to the assessment team. At a minimum, those groups who need to be involved in implementation of adaptation measures should be consulted and kept informed during the assessment.

The time period covered – what past and future time period should be considered? In many towns there is little information on climate change projections affecting their area. Or the information they have is not readily translated into practical guidance for adaptation. In those situations it is best to document and assess the impacts of past extreme events – and regular seasonable events – on the target area and assets. When considering climate change, how far out into the future should projections go and other influences in that time period need to be considered.

To help keep you and your team on track, be sure to save your scoping analysis and decisions in a scoping report. A simple table outlining your target infrastructure system, the geographic area and any additional scoping issues such as the need to consider overall watershed influences will suffice. Saving your scope in a document helps you to remember how and why scoping decisions were made and to revise your scope when necessary.

3. IMPACT AND VULNERABILITY ASSESSMENT

Defining the target infrastructure "system": Once you have defined the initial scope of the assessment, it is time to create a more detailed description of your target infrastructure system.

The system description should include:

- Details of the main infrastructure components (eg, an irrigation system might include the water source and catchment, sediment trap, pumps, canals, culverts, distribution pipes and command area).
- Services provided by the system's assets.
- Involvement of local communities in management and maintenance.
- The natural and social system components linked to the asset and affected by its condition and resilience (eg agricultural fields, school buildings, market and other infrastructure systems).

For some sectors, defining the target infrastructure system and its components is not straightforward. It requires interpretation and judgements by the assessment team. For example, a local feeder road that connects Town A to Town B may be 100km long. That entire road might be identified as the target infrastructure system, and all of its culverts, bridges and associated slope and drainage protection measures would be its elements. Or, the assessment team might decide to choose a short section of the road that has proved to be especially vulnerable to past extreme events such as floods and landslides. In that case the "system" would be the road section and the few elements within that section. Assessment teams will need to carefully define the boundaries of the assessment and the components of special interest.

Defining the infrastructure system objectives: What does your target infrastructure system do? Once you have identified your system, it is important to establish its objective or purpose and how each component contributes to that objective.

For example, a small irrigation system might deliver about 0.9 litres/s/ha of water to a command area of 300 hectares. Each element will have its own role in contributing to this overall objective which needs to be described, such as how the sediment trap objective is to keep sediment from entering and blocking the distribution piping and canals.

In your scoping report, write down your target infrastructure system's main objective. Then list each of the components that are part of that system and how each one contributes to that objective.

Including these details within the scoping report will help you remember why particular scoping decisions were made and will help you define vulnerabilities and adaptation measures in subsequent steps.

A system or component may have more than one objective. Taking the time to define primary and secondary objectives will also help you draft a more thorough vulnerability assessment and create a more effective adaptation plan.

Table 1 suggests guiding questions the team can ask to define the scope of their assessment

Table 1: Guidance for defining the scope of the vulnerability assessment

The infrastructure asset or system under focus
• Existing projects vulnerable to past climate variability or extreme events • Infrastructure of strategic importance to the nation, town or local community (eg road links to market or airport) • Poor quality or damaged infrastructure which needs to be replaced or repaired (eg repeatedly damaged by floods) • New infrastructure of strategic importance or affecting a large area or number of people • Representative of an infrastructure category and therefore valuable as a pilot for replication
The linked assets influencing the target system
• Other assets upstream, downstream or near the target system which influence its operation (eg drainage corridor, canal or river banks, dyke, agriculture or residential uses) • Degraded assets already affecting condition of the area or existing infrastructure • Assets which will be impacted by the proposed infrastructure system
The geographic area
• Area served by the target system (eg irrigation command area) • Area with potential to affect the target system • Area exposed to past extreme events and projected climate change threat • Area with potential as an accessible and representative demonstration for replication
The stakeholders to be involved
• People potentially affected by the existing or proposed infrastructure system • Area where communities are committed to participate in adaptation management, monitoring, and repair • Line agencies which will need to have a role in adaptation implementation or which are will need to provide essential information or approvals
The time period covered
• Historical record of temperature and rainfall as validation period for climate change projections • Time of past more extreme events affecting the target area • Time slice for climate change projections – eg 2030, 2050 • Life time of existing or proposed target infrastructure

3. IMPACT AND VULNERABILITY ASSESSMENT

STEP 2. CONDUCTING THE BASELINE ASSESSMENT

The baseline assessment of the target infrastructure system provides a strong foundation for the entire vulnerability assessment and adaptation process. It establishes the evidence base, justification and credibility for all the judgements and decisions that follow. The baseline assessment step can be the most time and resource consuming of the vulnerability assessment process. Once completed, your baseline will describe the past and existing situation, trends, and drivers that affect the target systems, and will provide an analysis of the changes to the system that will occur whether the climate changes or not (Figure 3).

Field assessment: To complete the baseline assessment, take a field visit to your target infrastructure system and complete the baseline assessment field template. Be detailed when you fill it out – the information you include will be used in subsequent steps in the process. The template is included as Appendix 1 in this volume.

Your assessment will include:

- A short description of your target infrastructure system, which you can pull from your scoping documents.
- A description of the watershed in which the system functions.
- A description of the system's location and any manmade or geographical attributes.
- A description of the state of the infrastructure (eg is it new, functioning, damaged, under repair?)
- Descriptions of any manmade elements in the system, including photos and illustrations where possible.
- A description of known past extreme events that impacted the system.
- Any adaptation responses to those extreme events, including recovery efforts.
- Expert judgement on the design and form of those manmade elements to withstand extreme events.

TOOLS/METHODS/INPUTS

It is often the case that information on past extreme events, such as floods and droughts, and the design details of existing strategic infrastructure is not available. Consider consulting with local people, experts, and government officials to fill in your knowledge gaps.

You may also engage in participatory mapping exercises to glean the necessary information. See Tools and Methods appendix 6 for more information on participatory mapping.

Creating a climate threat profile: Once you have collected all of the necessary information on past extreme events and the stability of the system, you can begin to apply climate change projections and variability to see how it may impact on your system and its surrounding area.

Preparing a climate change threat profile for the target area will be based on understanding and documenting the nature and impacts of past extreme events - eg past storms, floods or droughts.

Figure 3: Baseline assessment components

Asset inventory and priority setting

- Provide a description of the existing and proposed assets in the sector/area
- Describe the condition of the infrastructure systems

Past climate variability and extreme events

- Decribe the most significant past extreme events affecting the sector/area
- Describe impacts of that event

Adaptation audit of past protection measures

- Describe measures taken to learn from past from past extreme events
- Assess the effectiveness of those past "adaptation measures"

Socio-economic status and trends assessment

- Identify stakeholder "users" and affected communities
- Describe socio-economic trends of relevance to the asset

Natural systems status and trends

- Describe natural systems that affect asset (eg catchments, rivers)
- Describe the status and trends in those systems of relevance to system

Climate change threat and opportunities profile

- Gather all existing climate change projections relating to the area
- If feasible, conduct fresh climate change and hydrological modelling

3. IMPACT AND VULNERABILITY ASSESSMENT

To determine future climate threats, you will need to consult your national hydro-meteorology agency or institute for downscaled climate change and hydrological modelling for your area. If not available, then conclusions drawn from national projections on likely trends and ranges in changes affecting the target area will be adequate for the local vulnerability assessment.

To help keep track of all of this new data, note the following in the Vulnerability Assessment Matrix (Appendix 3):

- The particular change to the climate.
- The elements/system that this change will impact.
- How that impact will occur (the threat).
- The projection or modelling that you used to determine this result.

This Matrix acts as a record of your assessment and helps guide the plans you will draft based on your assessment. It can be used to add weight and legitimacy to your decisions when dealing with decision makers.

NOTES

It is not necessary to cover all climate change parameters. Focus on those which are most relevant to the target infrastructure system and its surrounding area.

Some climate changes may also prove beneficial. For example, increased rainfall may improve crop yields in a dry agricultural area. Any assessment should take care to consider parameters which might have positive effects.

TOOLS/METHODS/INPUTS

If you have the time and resources, you can conduct new climate change and hydrological modelling to ensure you have the most up-to-date information.

Figure 4: Examples of climate change threats

Flooding (eg fluvial and flash floods) and increased precipitation: threat of physical damage from intense flow and inundation, increased destabilization of nearby land, erosion, landslides.

Storms, strong winds, hail and lightning: physical damage to natural and built assets (eg houses, crops).

Drought: reduced water availability, sedimentation of canals, threat to productive crops, animal loss, drying/movement of soil/foundations leading to damaged structures, dust storms.

Low temperatures/frosts/cold snaps: crop losses, animal losses, damage to built infrastructure (eg expansion of ice and loss of structural integrity).

Temperature range changes: loss of species that are unable to adapt to temperature changes.

Heat waves: crop losses, forest fires, damage to physical infrastructure through heat expansion/ cracking (eg pipes).

3. IMPACT AND VULNERABILITY ASSESSMENT

STEP 3. ASSESSING THE IMPACTS OF CLIMATE CHANGE ON YOUR SYSTEM

A Vulnerability Assessment Matrix (Appendix 3 in this guide) provides the framework for documenting the assessment results. Table 2 provides an example of a completed vulnerability assessment matrix for a small irrigation scheme. This Matrix acts as a record of your assessment and is the basis for your adaptation planning. It can be used to add weight and legitimacy to your decisions when dealing with decision makers. Footnoting of reasons for various judgements made in each column of the matrix is a necessary part of building the case for your adaptation recommendations.

In the impact assessment you determine the effects of the identified climate change threats on the target system by considering its **exposure** and **sensitivity** to them.

Table 2. Vulnerability Assessment Matrix

Vulnerability Assessment Matrix example: Irrigation system with 68ha command area.
Major system components are:
1. Concrete weir across river with scouring sluice gate,
2. Gated off-take into main canal 3.5km in length,
3. Man canal concrete lined for 270m across landslide zones and incorporating retaining wall over 15m
4. 1 aqueduct, 2 footbridges and 4 division boxes to assist distribution of water
5. 1 inlet/outlet box to catch additional drainage flows from upstream into the main canal

Threat	Interpretation of Threat	Impact					
		Exposure	Sensitivity	Impact Level	Impact Summary		
Change and shift in regular climate	Interpretation of the threat for the system/area	refer to table			Written explanation of what the impact is, and why it was scored (very low to very high)	refer to table	
Increase in Max. temperature and evapotranspiration	• Increased crop water demand • Frost incidents decreased	1,2H	L	M	• Water required at intake slightly increased particularly for paddy land preparation • Second potato crops less susceptible to frost damage • Alternative cropping pattern could be introduced	M	M
Increased Rainfall	• Precipitation increase during early and mid-monsoon period •No impact on infrastructure	3L	L	L	• Could reduce water demand from the stream during monsoon period • Little effect on crop production	H	L

Increased River Flow (intake)	• Increases significantly during early monsoon	4M	M	M	• Little impact on crop production • Increased flow could damage system infrastructure	H	M
Change and shift in events							
Flash Floods (Intake)	• Increase in bed load during flash floods – might block or damage intake • Stream bed mostly rock so little chance of degradation	5H	6H	H	• Blockage of intake, leading to temporary restriction of irrigation water • Sediment entering main canal will restrict its carrying capacity	7M	H
Flash Floods (Aqueduct)	• Increased flood flows • Scouring of cross drainage channel bed and pier foundations	H	8L	M	• Canal water unable to be supplied to downstream areas	9L	M
Storms	• Increased rainfall intensity over cropped area	H	10L	M	• Crops could be damaged and difficult to harvest • Level terraces will absorb increased rainfall • Terrace banks protected with soya bean. Only vulnerable at start of monsoon	H	M
Drought	• Reduction of water availability in stream during late dry season and delay of monsoon flows	11M	M	M	• Could affect yields for the second potato crop and preparation for paddy crops • An alternative to the second potato crop could be introduced	12M	M
Landslides	• Where main canal passes crosses steeper land • Adjacent to streams or aqueduct structure	M	13H	M	•Wash out of main canal leading to loss of water supply to full irrigated area (there is no command area above this location, so if this one is damaged the whole system is at risk	14L	M

1 ET increases throughout the year with total demand over the paddy season May/October increasing by up to 380mm
2 Minimum temperature increase of up to 3 degree in March/April and frost probability in February reduced to only 5%. Less likelihood of damage to second potato crop
3 Monthly average daily rainfall increases slightly during early monsoon period (maximum of 5mm in July). However decreases post monsoon and during winter periods
4 River flow increases by some 80% during the May/July period. A 20 year return period flow could occur every 2 years. The rest of the year little change
5 100 year return period flood could increase in size by up to 100%Rainfall intensity will increase by 60%. Catchment area mostly forest
6 Well-designed weir across stream with scouring sluice. No spindle to adjust intake gate height to prevent sediment entering main canal during flood flows
7 Sediments collected in main canal can be manually shifted relatively easy with local labour
8 Gabions protecting cross channel bed and channel has adequate capacity for increased flows. New piers provided to support aqueduct.
9 Farmers cannot redesign or repair without technical assistance
- Cost USD10,000 to recently rehabilitate
- As recently improved it will have low priority for future funding

10 Wind damage to traditional rice crops only from storms prior to harvesting
11 River flows reduced by 50% with negligible flows predicted in March/April
12 Department of Agriculture providing agricultural extension services in the area
13 Remedial works already undertaken in sensitive areas to support main canal against landslide
- No catch drainage above landslide areas to reduce water logging of upper slopes

14 Farmers cannot repair damage on themselves
- As a recently improved system, it will have a low priority for funding

3. IMPACT AND VULNERABILITY ASSESSMENT

Exposure is the extent to which a system is exposed to the climate change threat. Sensitivity is the degree to which a system will be affected by, or responsive to the exposure. The potential impact is a function of the level of exposure to climate change threats, and the **sensitivity** of the target assets or system to that exposure.

Exposure to a threat depends on:

- **location** of the system with respect to the threat eg. distance from the flood zone or river bank.
- **threat intensity** e.g. how deep and fast flowing is the flood water, how heavy is the rain, how strong is the wind?
- **frequency** e.g. the "return period" of large, destructive floods – every five years, every 10 years?
- **duration** e.g. the flood threat lasts for 1 day, flood waters remain for 5 days.

Judgements based on the information on past extreme events need to be adjusted to account for the expected effect of climate change (e.g. increases in frequency and intensity of flooding event).

The rating system for exposure and other parameters uses a score from very low to very high. Rate the system and each component using your expert judgements and scientific data.

Exposure Scale

Very Low	Low	Medium	High	Very High
very low intensity/ severity and/or very infrequent and/or very short duration	low intensity/ severity and/or infrequent and/or short duration	medium intensity/ severity and/ or average recurrence/ average duration	high intensity/ severity and/or frequent and/or long duration	very high intensity/ severity and/ or very frequent and/or very long duration

Sensitivity: The next step in impact assessment is to rate the sensitivity. Sensitivity is the degree to which exposure to a threat will negatively affect the operation of the system. Sensitiviy may be influenced by:

- **Integrity of design:** Is the asset designed robustly and with features to mitigate against threats? e.g. Powered irrigation system to protect crops against drought; crop varieties resilient to frost/drought; drainage around buildings, roads, fields; buildings raised above flood line.
- **Integrity of materials and construction:** e.g. Does the asset contain strong, durable, appropriate materials in light of the expected threats? (E.g. buildings constructed of bamboo or concrete; unsealed dirt road or a paved road)
- **Geotechnical character:** e.g. bank stability, soil condition, drainage capacity and volumes, vegetation and existing stability measures. May require more formal geotechnical assessment or visual inspection.

Taking into account these variables, rate your system sensitivity from very low to very high:

Sensitivity Scale

Very Low	Low	Medium	High	Very High
very good integrity of design, materials, and construction	Good integrity of design, materials, and construction	average integrity of design, materials, and construction	poor integrity of design, materials, and construction	very poor integrity of design, materials, and construction

Impact: Assessing impact is the most important stage of the vulnerability assessment. Use the impact scoring matrix to score and document your results carefully on the impacts column of the Vulnerability Matrix (Appendix 3). Insert detailed footnotes explaining your choices in the VA Matrix – these will come in handy in the next step.

Impact is Exposure X Sensitivity. To determine the impact rating for your system, take your results from your Exposure and Sensitivity scoring and line them up along the Impact Scoring Matrix. For example, a system element that is assessed as having a Medium Exposure and a Low Sensitivity will generate an Impact Rating of Medium.

The detailed impacts you list in the VA Matrix will help define your adaptation responses in the next steps. When describing Impacts, remember there are of two kinds – (i) direct impacts, like a damaged road, and (ii) indirect impacts, where that damaged road prevents produce from reaching the market or children from getting to school. Listing both direct and indirect impacts will help you define adaptation options that address the most significant of both kinds of impacts.

Impact Scoring Matrix

		Exposure of system to climate threat				
		Very Low	Low	Medium	High	Very High
Sensitivity of system to climate threat	Very High	Medium	Medium	High	Very High	Very High
	High	Low	Medium	Medium	High	Very High
	Medium	Low	Medium	Medium	High	Very High
	Low	Low	Low	Medium	Medium	High
	Very Low	Very Low	Low	Low	Medium	High

3. IMPACT AND VULNERABILITY ASSESSMENT

STEP 4. ASSESSING THE CAPACITY TO AVOID OR RECOVER FROM THE IMPACTS

Adaptive Capacity: Once you have completed the impact assessment, you must assess the capacity of the managing organisation or community to prepare for and respond to the impacts. You will include the results of this assessment in the same Vulnerability Assessment Matrix that you worked with in Step 3. This step can be completed from your office.

To complete the assessment, take each of the impacts you listed in the Vulnerability Assessment Matrix and consider them against the appropriate factors in Table 2. Using these considerations, rank the organisation's adaptive capacity on a scale from Very Low to Very High. List your results in the Vulnerability Assessment Matrix using footnotes to explain your scores.

NOTES

It is not necessary to consider all impacts. The factors to consider will depend on the nature of your target system and the organisations involved in its operation. When assessing adaptation capacity of the responsible infrastructure department the most important factors are those of a cross cutting nature and those relating directly to the asset and its repair/construction.

This scale is an example of an organisation delivering and/or managing the infrastructure system (eg a road, irrigation system or water supply intake and pumping station).

Table 3: Factors to consider when assessing adaptation capacity

1. Cross cutting factors	**2. Infrastructure**
• The range of available deputation technologies such as bioengineering approaches. • Management and response systems in place. • Availability of relevant technical staff and knowledge. • Suitable financial resources to support climate change adaptation.	• Availability of physical resources for repair (eg materials and equipment). • Regularity of system maintenance. • Existence of backups in place (eg alternative routing for failed roads or bridges). • Presence of other infrastructure negatively affecting the system.
3. Natural Systems	**4. Social Systems**
• Condition and stability of watershed affecting the asset. • River bank slope stability. • Water quality (eg in the case of irrigation and water supply assets).	• Availability of insurance and other financial resources to respond to impacts. • Existence of "user groups" and other community arrangements. • Access to alternative services.

When deciding on ratings for exposure, sensitivity, impact and adaptive capacity, it is important to include justifications and explanations of your decisions in the Vulnerability Assessment Matrix. Notes included in your matrix will help others understand the reasoning behind your scores and increase the credibility of your final rankings. Also, reasons given for the exposure and sensitivity scores help you complete the impacts summary column of the matrix (Appendix 3).

Adaptive Capacity Scale

Very Low	Low	Medium	High	Very High
very limited institutional capactiy and no access to technical or financial resources	limited institutional capacity and limited access to techincal and financial resources	growing institutional capacity and access to technical or financial resources	sound institutional capacity and good access to technical and financial resources	exceptional institutional capacity and abundant access to technical and financial resources

TOOLS/METHODS/INPUTS

The information you need to assess adaptive capacity may not be readily available. Seek out information from the community and other experts to fill any knowledge gaps.

STEP 5. SCORING AND RANKING VULNERABILITY

The final vulnerability score is determined by considering the impact and adaptation capacity together. To do so, take the impact and adaptive capacity results of each of your threats and plot them on the vulnerability scoring matrix. Note your results in the Vulnerability Matrix.

An important point to keep in mind is that with increasing severity of impact, vulnerability of the target infrastructure system increases. Adaptation capacity has the opposite effect – with increasing adaptive capacity an infrastructure system would have reducing vulnerability. The vulnerability scoring matrix takes that inverse relationship into account.

3. IMPACT AND VULNERABILITY ASSESSMENT

Vulnerability Scoring Matrix

		Impact				
Adaptive Capacity		Very Low Inconvenience (days)	Low Short disruption to system function (weeks)	Medium Medium disruption to system function (months)	High Long term damage to system, property (years)	Very High Loss of life, livelihood, or system integrity
	Very Low Very limited institutional capacity and no financial resources	Medium	Medium	High	Very High	Very High
	Low Limited institutional capacity and limited access to technical and financial resources	Low	Medium	Medium	High	Very High
	Medium Growing institutional capacity and access to technical and financial resources	Low	Medium	Medium	High	Very High
	High Sound institutional capacity and good access to technical and financial resources	Low	Low	Medium	Medium	High
	Very High Exceptional institutional capacity and abundant access to technical and financial resources	Very Low	Low	Low	Medium	High

The aim of the adaptation planning process is to guide the preparation of an integrated adaptation plan to build resilience in the target infrastructure system or area that will ultimately be supported and funded.

Adaptation to climate change refers to actions taken by households, businesses, governments and communities to respond to the potential impacts of climate change. It can include actions taken to prevent, avoid or reduce the risks of those impacts (proactive adaptation), or in response to impacts as they happen (reactive adaptation). It can mean retrofitting and upgrading existing infrastructure and building adaptation measures into sector- and area-wide plans and into new infrastructure. Adaptation includes taking advantage of the opportunities that may arise due to climate change, as well as responding to negative impacts.
It involves developing a range of adaptation options for each of the main impacts you determined during your vulnerability assessment and then determining priorities for implementation that are built into an integrated adaptation plan. With limited resources it is not possible or necessary to do everything at once; choices must made on what is feasible and necessary now and what can be left to later planning cycles.

Adaption planning has three main steps:

i. Defining the options.
ii. Setting priorities among them.
iii. Preparing adaptation plans and integrating them into established development plans and budgets (Figure 5).

Similar to the vulnerability assessment phase, adaptation planning uses a matrix and a number of other tools to guide scoring. This adaptation planning matrix (Appendix 4) is applicable no matter what kind of target infrastructure system or area you are dealing with, whether it is a road or water supply scheme, or an urban settlement or river basin.

Your final adaptation plan does not need to follow the matrix outcomes precisely. Other factors may influence adaptation priorities. Also, in some cases the matrix results may appear counterintuitive. If an adaptation measure is critical to the operation of an entire infrastructure system but only scores medium priority for adaptation because of its high cost then the final plan should override the matrix result and stress its importance. This highlights the importance of using the vulnerability assessment and adaptation planning matrices as a guide to influence but not dictate the final decisions on adaptation priorities.

4. ADAPTATION PLANNING

Figure 5: Adaptation Planning Process

6. Identifying adaptation options to address impacts			7. Prioritising adaptation	8. Preparing plans and supporting measures to ensure implementation	
Review Assets	Review Impacts	Identify options	Set Priorities	Prepare plans	Mainstream plans
Review most vulnerable systems and assets, threats they face	Review all impacts for system, assets, components, group by which could be addressed together	Identify range of adaptation measures to address each impact, group. Options can relate to system, assets	Identify options or groups of options that are most important, feasible, and bring the most benefits	Identify linkages between options, their actions, and phasing and integrate them into a plan	Define budgets and supporting measures, modify sector development polices as required

NOTES

It is feasible to go directly from the vulnerability assessment phase to defining an adaptation plan without using the Adaptation Planning Matrix. The matrix provides an additional set of tools to identify the most significant problems that need to be addressed and to choose which adaptation responses should receive attention in situations of scarce resources. Each team charged with taking climate change into account when preparing plans for areas or designing infrastructure systems needs to consider the level of effort and justification which is required in setting adaptation priorities. Completing the Adaptation Planning Matrix gives you another tool that you can use to add legitimacy to your adaptation plan when communicating with decision makers.

STEP 6. IDENTIFYING ADAPTATION OPTIONS TO ADDRESS IMPACTS

Reviewing the threats and impacts: The adaptation planning phase focuses on the most vulnerable assets and areas identified during the VA. First, review the threats and impacts identified for the system elements that scored High or Very High on the Vulnerability Scoring Matrix. Transfer these impacts on to the Adaptation Planning Matrix; you will be working with these impacts throughout these steps. The intention is to confirm the vulnerability assessment findings and ensure that all the most serious impacts are addressed.

Identifying Adaptation Options: Adaptation options are shaped by:

- Existing conditions at the target location.
- The climate change threats.
- The potential impacts on the infrastructure systems being assessed.
- The capacity of the system to recover from the impact.

Adaptation options fit within four scales:

1. **Area-wide Adaptation**

The first response is to look broadly at the entire area where the target system is located. This may mean, for example, looking at the host town, commune, catchment, river basin or protected area and thinking through an overall area-wide approach to adaptation. Setting a framework of broad principles for adaptation may help shape the more specific measures for the target system and its elements. It also promotes integration of adaptation measures across sectors and areas and seeks to avoid mistakes that could reduce resilience in other areas.

Table 4: Adaptation Planning Matrix

Threats	Impacts	Adaptation Options	Priority Adaptation		
Insert all H and VH threats, first for the system as a whole and then for each of the H and VH components.	Insert the impacts recorded for the H and VH threats (only consider direct impacts)	Listing of the adaptation options in addressing each of the most significant impacts – focus on structural and bioengineering options	Feasibility cost, skills, staff, equipment	Effectiveness how well does it avoid, reduce or eliminate the threat	Priority

2. **System-wide Adaptation**

The second response is to identify adaptation options for the target infrastructure system, whether that is an irrigation scheme, river embankments, or feeder road, etc.

3. **System Component Adaptation**

The third response is to determine the adaptation requirements for each of the key system components that you outlined in your scoping document. For example, if your target infrastructure system is a road, you may need a culvert bridge. A river dyke system may require bioengineered slope stabilisation.

4. **Supporting and Facilitating Adaptation Measures**

The fourth response is often overlooked because it can be the most complex and involve many authorities and stakeholders. To be effective, many of the measures defined for the area or system may require supporting actions by other sectors, areas, resource managers, or levels of government. It may involve establishing new decision-making and management structures. It may involve introducing new procedures like spatial planning and zoning for safeguards. It may involve more detailed modelling of hydrology to better inform infrastructure location and design. A comprehensive adaptation plan needs to be a combination of mutually reinforcing actions using natural, built, social, economic and institutional systems.

At this stage, when filling out the Adaptation Planning Matrix, list all options regardless of how feasible they seem. You will refine your list at a later stage. You don't need to develop detailed designs for your options yet, but it is important to establish certain guiding principles at the outset. In general, it is best to consider adaptation options that take wider ecological, social and economic factors into account as early as possible. Green infrastructure options contribute to overall sustainability beyond just the target infrastructure system and should be implemented as much as possible.

The Green Infrastructure Volume in this resource kit (Volume 2) contains more than 25 green infrastructure techniques. Including solutions from the Green Infrastructure Volume will ensure that your list contains strong, viable, and sustainable adaptation options.

When listing your adaptation options, be sure to footnote how the action will modify vulnerability, either by minimising exposure, reducing sensitivity or by building adaptive capacity.

Your main focus should be on defining adaptation measures for the target infrastructure system; supporting measures such as policy and institutional reforms can be an ongoing consideration once you move into more mature phases of the adaptation planning process.

NOTES

It is important to draw from international, regional and local experience to find out what has worked in building resilience to extremes in the past.

Reviewing international experience can expose planners to new approaches, technologies, materials and even institutional arrangements and policies which have worked well in other countries.

And, to ensure best results, identify measures that fit within the mandate of your immediate stakeholders. Then progressively identify what others can do to reinforce your core measures and to promote their sustainability and replication.

Table 5 illustrates categories of adaptation options and the key actors responsible for implementation.

TOOLS/METHODS/INPUTS

Identifying adaptation options requires the involvement of a cross-sectoral group of specialists as well as affected stakeholders. In most cases, adaptation will require action and commitment from local affected groups, so their involvement at each step should be facilitated. As in other phases of the process described in this guide, the extent and nature of consultation will depend on resources available, urgency for action, and the level of decision-making.

Table 5: Adaptation options categories and examples

Adaptation Category	Specific Measures	Main Responsibility
Bioengineering Measures	• Flood protection: dyke drainate system; flood storage reservoir; erosion protection; bridges; road culverts, etc • Water storage (eg dams, tanks) for use during dry months • Reinforcing existing structures or building new ones to withstand sever storms and wind	From district to national level government, can involve local user groups
Bioengineering Measures	• Flood protection: dyke drainate system; flood storage reservoir; erosion protection; bridges; road culverts, etc • Water storage (eg dams, tanks) for use during dry months • Reinforcing existing structures or building new ones to withstand sever storms and wind	From district to national level government, can involve local user groups
Traditional local adaptation measures	• Bamboo stakes and vegetation in river banks • Maintenance of traditional water sources and water user groups • Use local natural mateirals and designs in construction of houses, rock wals, and wind breaks • Re-vegetating fordunes and mud flats with local native species and re-estabilishing mangroves to combat erosion • Maintaining fish traps and reviving community gardens that diversify livelihood options • Traditional seed storage facilities	Land owners, user groups, local govenrment level

4. ADAPTATION PLANNING

Economic instruments	• Natural resource and land use taxes • Payments for ecosystems services • Grants and tax reductions • Conditions on licenses and permits	National or provincial government
Natural systems management	• Revegetation of watersheds • Rehabilitation of river embankments and flood plains • Establishing biodiversity corridors • Effective management of protected area network and buffer zones • Greening of urban areas • Agro-forestry practices to increase species complexity and stability • Water allocation systems to share limited water supplies during drought	National or provincial government with delegated responsibilities to user groups
Social responses	• Resettlement programs • Livelihood and crop diversification • User groups for maintenance and management of facilities/resources • Seasonal and planned migration • Education and awareness programs	Local communities, national or provincial governments
Policies and regulations	• Zoning for development control (eg no major structures • Regulatory requirements for structural integrity of buildings, material controls, floor height restrictions • Sector design standards (eg of culverts, materials, setbacks) • Urban zoning and safeguards • EIA and SEA provisions and tools which consider climate change	National or provincial government
Research and development	• Research into drought/saline tolerant crops • New porous surface materials to allow for water penetration in urban areas • Tolerance levels and adaptive capacity in wild species and ecosystems	National or provincial government, institutes
Industrial responses	• Formation of local user groups for management and maintenance of infrastructure facilities • Structures for promoting partnerships with business and the community • Programs to integrate climate change within disaster risk management agencies • Creating inter-agency networks on climate change that encourage collaboration between organisations	National or provincial government

STEP 7. DEFINING THE PRIORITY ADAPTATION MEASURES

Fundamentally, adaptation planning is all about prioritising. It is not possible or necessary to do everything at once. Some investments need to be made immediately or soon, while others can be left until more resources become available. Your first priorities should fit within available funds and address the most serious vulnerabilities in the systems and elements that are most important to your target area, sector, or community.

Your first priorities should also lay the foundation for future adaptation investments and facilitate future additions and modifications as the climate continues to change. The best adaptation measures facilitate future adaptation within and outside your target infrastructure system instead of making them more difficult or expensive.

Strategic options for adaptation: There are four approaches to adaptation.

i. Build now for lifetime adaptation.
ii. Plan for phased adaptation over project lifetime.
iii. Progressive modification to design.
iv. Build to repair.

Table 6 describes those options and their operational and financial implications. In most cases **planning for a phased approach to adaptation over the lifetime of a project** is the most effective approach. It may not be a matter of choosing between options but staging them – some will need to be implemented before others are feasible.

Once you have developed a full list of adaptation options and chosen which of the four approaches your adaptations will follow, you can begin to prioritise. It won't be feasible or necessary to implement all possible solutions. Some of the options may cancel each other out. For example, it may not make sense to build a flood retention dam as well as raise the level of a downstream bridge. Also resource limits, and policy or regulatory limits and standards may favour certain options over others.

The next step in the adaptation planning matrix is to assess the **feasibility** and **effectiveness** of each adaptation option to arrive at a rating of priority.

Feasibility of an adaptation option: Feasibility is the extent to which each option can be accomplished or implemented. Factors that influence feasibility include technical complexity, capacity of the infrastructure management agency and user community and the cost.

4. ADAPTATION PLANNING

Table 6: Four approaches to design of adaptation measures in infrastructure

Adaptation Approach	Description of adaptation approach	Expected Financial Implications
Build now for lifetime adaptation	• Build all adaptation measures immediately to last the project lifetime.	• Relatively high investment initially. • No additional investment for subsequent adaptation required. • Long term security is dependent on actual climate change not exceeding predictions.
Plan for phased adaptation over time	• Fully plan an upgrade program to progressively adapt the design as climate change occurs.	• Medium level initial investment. • Investment required during asset lifecycle. • Implementation of project adaptation phases will occur as designed.
Progressive modification to design	• Redesign and reconstruct as required in response to verified climate change. • Initial design may not provide functionality to adapt over lifespan. • Redesign and reconstruction required prior to damage or failure.	• Lower initial investment. • Climate changes will force redesign costs and investments for reconstruction during asset lifecycle to avoid catastrophic failure. • This is potentially an expensive approach.
Build to repair	• Accept that there will be damage and repair is required. • Initial design does not incorporate adjustments to respond to climate change projections. Should the asset be damaged, asset manager accepts damage and carries out repairs.	• Low initial investment. • Likely financial loss due to damage of asset. • Relatively high repair cost during lifecycle but overall may lead to lower whole life costs if climate change does not cause substantial damage. • This is the cheapest up-front option but comes with the largest risk and potential cost.

1. **Technical complexity and demands:** Does the affected community or lead government agency have the knowledge and skills to use the technologies involved? Is the technology available within the country? Does it come with high maintenance demands and costs? Will it require investment in time and resources to understand how it can best be applied locally?
2. **Time to implement:** Implementation time can be a critical factor in situations where past and existing extreme events have caused damage or threaten strategic infrastructure and facilities. Also, some options such as a river bank dyke may need to be fully in place to be effective where others can or need to be implemented over several years. For example, to stabilise a bank with bioengineering methods may take a short time to put in place, but years to mature and increase in strength and resilience.
3. **Capacity of local communities:** If local communities are an essential force in building, managing, and monitoring the adaptation measure, many issues will need to be considered through consultation and survey. Who within the community will take on the responsibility; Will special management groups need to be assembled? Will the key actors be able to manage work and home roles with new duties? Will compensation be needed? It is not necessary for the adaptation team to resolve all issues relating to local community involvement, but it is important to discuss how much effort will be required to establish community management.
4. **Capacity of government:** In most cases, even for national infrastructure assets, local government will have a role in adaptation management, monitoring, and repair. If responsibilities fall to local agency staff, duty statements and performance evaluation criteria will need to be revised, new budget items introduced and sourced, and equipment and supplies drawn together to meet the demands. Information and capacity strengthening activities may also be needed.
5. **Cost**: Cost has been left to last in this list because it can be a “show stopper”. High cost can easily prevent action or lead to sub-optimal adaptation strategies, especially when important options require phased funding over the long term. It may be tempting to score expensive measures as having low feasibility, even if they are critical to the effective functioning of a system or the safety of affected communities. It may be best to leave cost out of your feasibility assessment at this stage. Like adaptation plans, budgets are all about prioritising, and you may find that you have enough funding once your whole plan has been prepared.

While the above factors do not require official scoring, the Feasibility Rank can act as a guide. Once you and your team have established a feasibility rank for each of your options, note the results in the Adaptation Planning Matrix. Be sure to record how you established the rank as these notes will add legitimacy to your choices when communicating with decision makers.

TOOLS/METHODS/INPUTS

The final ranking from very low to very high feasibility is made based on expert judgements of the information gathered during the baseline and impact assessment phase. Establishing feasibility is a matter of discussion and consensus. In a workshop situation, for example, feasibility and effectiveness can be defined through group sessions over a few hours by drawing from the baseline assessment, vulnerability assessment matrix, and field visits.

Flexibility Rank

Very Low	Low	Medium	High	Very High
requires additional R&D, very lengthy implementation, very limited technical and institutional capacity, cost vastly outweighs potential effectiveness	may require additional R&D, lengthy implementation, limited technical and institutional capacity, cost outweighs potential effectiveness	established technique, implementation matches effectiveness, growing technical and institutional capacity, cost in line with potential effectiveness	established and tested technique, implementation matches or better effectiveness, sound technical and institutional capacity, costs match or better potential effectiveness	established and tested technique in GMS, implementation matches or betters effectiveness, exceptional technical and institutional capacity, costs match or better potential effectiveness

Effectiveness of adaptation options: The next step in priority ranking is to determine the degree to which each adaptation option would produce the desired result. You will establish how successful each option would be at avoiding or reducing the negative impacts of climate change and enhancing any benefits. Implementing options that reduce negative impacts while enhancing benefits effectively build resilience into your target infrastructure system.

The best adaptation options will also increase the wellbeing of affected communities, especially disadvantaged groups, and the natural systems they live within.

Ask the following questions to assess how effective an adaptation option will be at eliminating or reducing the impact:

- Will it eliminate the impact?
- If not, by how much will it reduce the impact?
- Will it take some time to become effective (eg several years for the root system to establish in a bioengineered slope)?
- How long with the adaptation measure last?

Use the effectiveness rank tool to establish a rank for each adaptation option.

Once you have ranked each of your adaptation options, note the results in the effectiveness column of the adaptation planning matrix. Be sure to record how you reached each rank, as these notes will add

Effectiveness Rank

Very Low	Low	Medium	High	Very High
will not eliminate or reduce the impact, many years to take effect, short life span	will only marginally reduce impact, slow to take effect, short life span	moderate reduction in impact, some time to take effect, medium life span	reasonable reduction impact, quick to take effect, medium to long life span	eliminates or near eliminates impact, immediately effective, medium to long life span

legitimacy to your choices when communicating with decision makers. You can also use the notes to help develop monitoring and evaluation indicators in the next steps of this process.

Ranking Priority: Priority is a function of Feasibility X Effectiveness. To determine a priority ranking for each of your adaptation options, take the results from your feasibility discussions and the results from your effectiveness ranking and plot them on the Priority of Adaptation Matrix. Note the final rank in the adaptation planning matrix.

Priority of adaptation = Feasibility of adaptation action x Effectiveness in addressing impact

Priority Scoring Matrix

	Effectiveness in dealing with impact					
Feasibility of action		Very Low	Low	High	High	Very High
	Very High	Medium	Medium	High	Very High	Very High
	High	Low	Medium	Medium	High	Very High
	Medium	Low	Medium	Medium	High	Very High
	Low	Low	Low	Medium	Medium	High
	Very Low	Very Low	Low	Low	Medium	High

NOTES

In some cases, important adaptation measures will not score well on your Priority of Adaptation matrix. Cost, time to implement, and other factors may reduce a score even when expert judgement has established that the measure is critical. If through your community consultations, a particular measure or set of measures has emerged as necessary, it should be considered high priority even if it hasn't scored as such on the matrix.

4. ADAPTATION PLANNING

STEP 8. PREPARING THE ADAPTATION PLAN AND SUPPORTING MEASURES

There is no "right" way to structure an adaptation plan. Your plan will depend on the size and complexity of your target infrastructure system. If it is a large system with many elements and managing bodies, your plan will consist of many pages and components. However, if your target infrastructure system is something smaller, like a reinforced stream bank, your plan may come in the form of a short brief.

The templates and matrices you have filled out along the way will help you in crafting your plan. You have defined what you will need to implement, how, when, and with whom in order to make your target infrastructure system more resilient to climate change and other impacts. Now it is a matter of taking those details and assembling them in an integrated way.

Laying out your adaptation plan:

Scope: It is best to start your plan by laying out the scope, which you defined in the first step. Your scope may look different now than it did in the beginning of your process. Be sure to include the most up-to-date version of your scope to account for any changes.

Target infrastructure system: Using materials from your baseline assessment, describe your target infrastructure system. Describe its main elements and overall objectives.

Adaptation measures: Take the adaptation measures that scored well in your adaptation planning matrix and arrange them in roughly the order you identified in your prioritising step. Describe them in detail, including how each measure pertains to either a particular element or the system as a whole. Taking information from your vulnerability assessment matrix and your adaptation planning matrix, explain how each measure will address impacts and build resilience in the system.

Adapting to opportunities: Identify any positive climate change effects and opportunities and what "adaptation" measures are needed to take advantage of those opportunities.

Institutional arrangements and responsibilities: Describe how the adaptation plan will be implemented. Include the agencies involved, any special institutional arrangements, and any local user groups or community organisations. Include funding sources where possible.

Time: Estimate how much time each measure will take. Set your measures up in phases:

i. Immediate (1 year)
ii. Short (2 years)
iii. Medium (5 years) or
iv. Long Term (10 years or more).

Identify the urgent measures and those that need to be taken before others are possible.

Adaptation impact assessment: Describe how your adaptation plan as a whole will help avoid or minimize negative impacts and enhance benefits.

Other development influences: Development doesn't happen in a vacuum. Describe other development factors that could affect implementation or influence the system and its adaptation measures. Identify additional actions needed to control or work with other influences.

Sectoral reforms: Identify any adjustments that should be made within the target sector in order to implement or replicate your adaptation measures and plan. This could include revising guidelines, improving design standards, and strengthening policies. This section provides the opportunity to make recommendations to help mainstream adaptation so that measures can be rolled out more efficiently in other areas.

Collaborative approaches: There may be measures that are outside the capacity and authority of a single national and local government agency. These will require a more coordinated, all-government approach. In these cases, identify the bodies you envision will need to be involved and describe how you imagine that kind of collaboration would work. This will help identify who you will need to have discussions with in your implementation phase.

5. ADAPTATION IMPLEMENTATION AND FEEDBACK

Ultimately, the goal with adaptation and implementation is to integrate this kind of process into regular development. Monitoring, periodic impact assessments, and improvements need to be instituted and budgeted for. By making these activities a normal part of development, you are mainstreaming climate resilience and sustainability.

More than the previous sections, this section is a work in progress. It reflects cutting edge strategies in global adaptation implementation.

Figure 6 describes the four main steps in adaptation implementation.

Figure 6: Adaptation implementation and feedback process

9. Design and construction with consultation	10. Monintoring with regular maintenance, repair	11. Phasing, adjustment and retrofitting	12. Audit, replicate, and commit to cyclical adaptation
Design and construct	Monitor and repair	Phase and adjust	Replicate and repeat
Design may involve hot spot avoidance, bioengineering, rehabilitation of natural systems, development controls and setting up community management and maintenance processes	Investment in monitoring of landscape and system, early warning of potential of failure, effectiveness of adaptation, program of regular maintenance involving communities.	Keep to planned phasing of adaptation measures based on latest climate change information and lessons from implementation, make adjustments, retrofit, and invest in responses.	Conduct adaptation audits and replicate what works well in other areas, ensure policies and procedures are in place to lock VA&A into development and planning cycle.

STEP 9. DESIGN AND CONSTRUCTION OF ADAPTATION MEASURE

There are several good guides that describe the processes involved in building and maintaining infrastructure. The Green Infrastructure Volume of this kit (Volume 2) contains several case studies that explain how others have implemented large and small adaptation plans.

Design: At its heart, design and construction takes the plans you drafted in the previous stages and turns them into a set of instructions for implementation. Your instructions will fall into two categories:

i. Structural
ii. Non-structural

Structural instructions encompass designs of physical interventions. For example, if you are using live fascines (Green Infrastructure 4.3) to stabilise a stream bank, engineering instructions will cover the details of how those fascines will be implemented, the amount of materials needed, and the skills required. At the procurement stage, it is important to hire contractors and workers who have some familiarity with bioengineering and climate resilient construction. Either that or you will have to arrange for training.

Non-structural instructions will cover how to implement the necessary policy changes, training regimes, and institutional activities that you outlined in your adaptation plan. These non-structural instructions will become more important in your monitoring and maintenance phases.

NOTES

The most important consideration at this stage is to ensure that the measures identified to adapt to impacts outlined in the vulnerability assessment aren't forgotten. If you have been working alone up to this point, or if you have not had construction experts as part of your team, it is crucial that you communicate how important it is that adaptation measures be designed in such a way that they actually perform the functions that you need them to.

Strong links between the vulnerability assessment team and the design and construction team will help ensure that adaptation needs are met. That way, you can take designs and weigh them against the elements and objectives that you outlined in your scope and vulnerability assessment. Do the designs account for each of the vulnerabilities and threats you identified? Has anything been overlooked or left out?

In the other direction, strong links will also ensure that you are made aware of any changes that become necessary if design and construction reveals new information. If you receive new information quickly enough, you will be able to refine your adaptation plan without losing too much time.

5. ADAPTATION IMPLEMENTATION AND FEEDBACK

STEP 10. MONITORING, MAINTENANCE, AND REPAIR

One of the main challenges in implementing adaptation measures is ensuring that new technologies are properly operated and maintained. Keeping your adaptation plan in place and functioning well requires monitoring and attention to detail.

Effective monitoring programs are an essential part of adaptation. They track how well – or if – your adaptation measures are mitigating the impacts they were intended to address and provide you with the data you will need to adjust as climate and other circumstances change. If you have a phased approach to your adaptation plan, monitoring will alert you to when key infrastructure pieces are finished so the next ones can begin. Monitoring programs also alert you to any weaknesses in the system so you can repair them before they cause further damage.

Appendix 7 provides a template to help you organise your monitoring and maintenance efforts.

Table 7: Monitoring and Maintenance Framework

Adaptation Measure	Monitoring Focus	Frequency	Responsible Entity	Organisational Indicators	Technical indicators
Short-term Measures					
Long-term Adaptation Measures					

Here are a few things to keep in mind while putting together a monitoring and maintenance program:

1. **Human resources:** A strong monitoring and maintenance plan depends on high quality inputs from affected local communities and the agencies responsible for managing your target infrastructure system. Local community assistance is especially important in vulnerable areas where government capacity and resources are limited.

   You will have already identified possible community partners in your adaptation planning process. Now is the time to engage and organise those partners.

   You will also have identified the government divisions that are responsible for your target infrastructure system. If at all possible, ensure that you coordinate local community efforts with those of government specialists and experts, or delineate responsibilities.

2. **Capacity building:** Your community groups and local experts may not be trained in green infrastructure or climate resilient development. To ensure high quality monitoring, you will have to engage in skill building efforts. These efforts should be tailored to your specific adaptation measures and your measurable indicators. You can also equip them with tools like the "Walking the Route" tool included in Appendix 8 that outlines how to audit a road/slope, what to look for, and how to record the findings.

3. **Measureable indicators:** Your community groups and local experts will do little good if they have no guidelines and nothing to measure. These indicators may be process based to measure progress in implementation or outcome based to measure the effectiveness of your adaptation plan. Developing indicators at the project level is relatively straightforward. Many infrastructure projects come with established monitoring and evaluation systems with proven indicators that already exist. Furthermore, your scoping process and vulnerability assessment already indicated the objectives of your target infrastructure system and its elements and the specific impacts you intend to address. However, monitoring and evaluation on a broader scale – say for an entire town or catchment – can be more complex and will require creativity and strong coordination across sectors.

4. **Feedback mechanisms:** High quality monitoring depends on a clear description of the objectives of the adaptation measures and how they link to the broader goals. Once collected, your monitoring teams need a way to relay that information back to decision makers. Your plan should include a means by which your teams can communicate their findings, be they regular meetings, web-based feedback forms, or other systems. Having access to your team's findings will equip you with the data you will need to procure funding for repair and rehabilitation.

Figure 7 Components of a Monitoring and Maintenance Plan

Human resources
- User and oversight groups, involvement of local community
- Specialists, staff from government division responsible for infrastructure

Capacity building
- Training for community members in running groups, monitoring
- Training for local staff and other experts in climate resilient building

Measurable indicators
- Impacts on elements, objectives from vulnerability assessment
- Health and stability of implemented adaptation measures

Feedback mechanisms
- Systems to collect and synthesise data generated by community and experts
- Links to filter results to decision makers

Funding
- Major budget items for disaster recovery, infrastructure repair
- Embed maintenance for adaptation into normal repair processes

5. **Funding:** Most countries include a major budget item dedicated to covering the costs of maintaining and repairing infrastructure after normal wear-and-tear or after catastrophic weather events. Rooting your monitoring and maintenance program into this budget item will help to mainstream the process and ensure that you have adequate funding to repair any weaknesses you find.

TOOLS/METHODS/INPUTS

Core groups such as those whose stories are included in this resilience kit may provide you with a viable monitoring and maintenance model. While your monitoring team may be smaller than the core groups discussed, the groups cover a breadth of technical skills and community perspectives that may prove to be necessary for thorough, consistent monitoring and regular feedback. Links between similar groups in the region could also complement in-house capacity building, as could visits to other sites employing similar techniques.

NOTES

Practical difficulties in conducting a monitoring program stem from a general lack of financial, human, and technical resources and capacities; a lack of baseline data and historical trends; uncertainty in projected climate change impacts; and insufficient sharing of information across stakeholder groups, levels and sectors. As a result, monitoring is one of the weakest areas of adaptation practice. This entire process equips you with the materials necessary to help overcome these challenges. The goal is to mainstream this type of adaptation planning and monitoring into existing development frameworks.

STEP 11. ADAPTATION PHASING, ADJUSTMENT, AND RETROFITTING

A successful monitoring and maintenance program should lead to progressive improvements in your target infrastructure system. As technology and expertise improves, your monitoring program should highlight areas where you can implement these advances, thus allowing you to "keep up with the times." It should also help shape any future adaptation measures, as you will be progressively learning from the adaptation and implementation process and applying knew knowledge to new adaptation plans.

Phasing: Some of the adaptation measures you identified in your adaptation plan may be scheduled for implementation in later phases of the infrastructure system. This can be for many reasons, including:

- The need for supporting infrastructure pieces to be in place first.
- Planned funding that comes later than your initial investments.
- Time needed to increase education, capacity, and training amongst community and local experts.
- Verification that the impacts of extreme events are occurring as projected.

A well-functioning monitoring program will alert you to when – and if – your subsequent phases should be implemented. You will be able to check your monitoring results against budgets, community realities, and new trends in climate change and climate projections.

Your monitoring program will also alert you to when you need to make adjustments to your plan. To adjust effectively, you need:

- Capacity in national and local government.
- Capacity in communities.
- A policy commitment to take action on adaptation monitoring and review findings and recommendations.
- The skills and technology necessary to rehabilitate, retrofit, and reconstruct infrastructure components as needed.
- Funding.

Adjustment and Renewal: Some adaptation measures identified in adaptation plans are scheduled for implementation at later phases of the infrastructure systems life depending on climate change projections. The need for those later measures should be kept under review based on regular updating of climate change and hydrological information and regular on site inspections of asset and surrounding conditions. One tool described in Appendix 8 – Walking the Route – is designed for that kind of site and asset inspection.

The results from an effective monitoring program should lead to progressive improvements in infrastructure performance and help shape future adaptation measures. That requires capacities in national and local government, as well as in communities to take actions to make those adjustments on a regular basis. There needs to be a commitment in policy to action on adaptation monitoring and review findings and recommendations, the budgets to do so, and all the necessary skills and technologies to rehabilitate, retrofit and reconstruct infrastructure components as needed.

Infrastructure departments already spend a large part of their budgets in maintenance and repair, most often when failures occur following landslides, floods, droughts and other extreme events. It is necessary to build on that considerable effort by making it more proactive and anticipatory so that interventions are possible before major failures occur. For that to be possible investments are needed in regular updating of climate change downscaling, in hydrological modelling by catchments and in providing practical information to infrastructure sectors on demand and tailored to their needs. The benefits of that improved service will begin to show in more sensitive infrastructure siting and design.

5. ADAPTATION IMPLEMENTATION AND FEEDBACK

STEP 12. REPLICATE AND UPSCALE

Adaptation auditing: The experience with implementing adaptation measures should be documented in regular adaptation audits. "Audits" can describe case studies of what has and has not worked. They can focus on measures that have been long practiced in the region, for example bioengineering techniques for slope and river bank stabilisation. Also they can be conducted every few years of adaptation approaches used in recent infrastructure development and which might involve new technologies and materials. The aim is to build on and replicate the best examples of good adaptation through the sector infrastructure programs.

Upscaling of good adaptation field practises means making the necessary reforms to policies, institutional arrangements, and procedures at higher levels, which will enable good practices to be applied systematically within the sector and in other areas.

Green infrastructure: The other prerequisite to realising anticipatory adaptation is through intensive attention to testing and demonstration of fresh approaches. A guiding principle for that piloting is to respect and build on natural features and systems. This often means using measures that are based on traditional knowledge and practices, as well as those which have been practiced by sector agencies for many decades. These techniques are often called bioengineering methods or more broadly green infrastructure.

Green infrastructure is about changing the way roads, drains, flood gates, river embankments, water supply and sanitation facilities, power supply services and buildings are designed and managed to be ecologically sustainable and resilient to climate change. As detailed in Volume 2 of this Resource Kit, green infrastructure includes an array of products, technologies and practices that use natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality, the infrastructure service and its resilience to climate change.

Progressively, infrastructure line agencies need to take on the responsibility for review and adjustment to their own planning and management instruments to accommodate climate change adaptation on a regular and cyclical basis. For that each sector will need to embrace the preparation and regular review of Sector Adaptation Plans of Action in keeping with the cycles of their development planning and budgeting.

6. OPTIONAL STEPS AND TOOLS FOR LARGE SCALE PLANS AND PROJECTS

In cases of large-scale projects, programs of national strategic importance, or projects that affect large populations or areas, a vulnerability assessment team can add rigor to the vulnerability assessment by

i. Taking a quantitative approach to the scoring rather than applying the very low to very high rankings.
ii. Adding a step following the vulnerability assessment to assess the significance of the impacts.

When large investments are involved the government may call for added certainty and justification of the team's adaptation recommendations. Adding either or both these methods can provide further evidence to justify and refine specified courses of action.

The quantitative approach to the vulnerability assessment scoring is not described in this guide. It is set out in an accompanying guide. Here, the significance assessment step is presented.

Estimating Significance of the Impacts (risk assessment): A vulnerability assessment identifies the direct and indirect impacts of various climate change threats on a system and its components. It can be valuable for a team to think through in greater detail the impacts they have identified and to understand and document them more fully. Determining the significance of those impacts can lead to a more detailed ranking of impacts and assist in setting adaptation priorities. Also, it can inform decision makers of the level of risk associated with the impacts.

"Significance" is a term widely used and understood among environmental impact assessment practitioners. In the field of Disaster Risk Management, however, the equivalent term is "risk assessment". The challenge with that DRM term is that it has many meanings and associated methodologies and is used in many sectors and industries. For example, it is the foundation of the life insurance sector. For the purposes of this guide, the estimation of significance can be viewed as a risk assessment method.

Significance is likelihood of the impact occurring X seriousness of the impact. The resulting significance of each impact provides a first guide to priority setting among adaptation options. Significance is assessed on a scale of very low to very high interpreted as follows:

Likelihood is the chance or probability of something happening. If an impact is very significant but there is little probability of it happening – for example catastrophic failure in a hydropower dam – a team of planners need to make a judgement on what is an acceptable level of risk for each potential impact. The assessment of likelihood provides the team with the initial information needed to make that judgement.

It is a challenging stage of adaptation planning. Even if there is very little chance of an event happening, the consequences could be so serious in terms of potential loss of life and property that a team could choose to override the matrix results and assign highest priority to adaption measures designed to avoid the impact. Dam failure, for example, can have such serious impacts that, even if unlikely to happen, it would necessitate extensive safeguards and adaptation measures.

6. OPTIONAL STEPS AND TOOLS FOR LARGE SCALE PLANS AND PROJECTS

Seriousness criteria used for assessing seriousness of impacts include:

- Loss of life.
- Loss, damage to, or destruction of property.
- Loss of productivity and income.
- Impediments to socio-economic functions.

Environmental criteria may also be important for some areas. If your target area is in a forested area, seriousness might encompass degradation to endangered species habitat or resources essential for local livelihoods.

To "score" significance, plot your likelihood and seriousness rankings on the Significance Matrix.

Significance of Impact = Likelihood of impact happening x Seriousness of impact

Significance Scoring Matrix

Likelihood of impact occuring	Seriousness of impact				
	Very Low	Low	Medium	High	Very High
Very High	Medium	Medium	High	Very High	Very High
High	Low	Medium	Medium	High	Very High
Medium	Low	Medium	Medium	High	Very High
Low	Low	Low	Medium	Medium	High
Very Low	Very Low	Low	Low	Medium	High

Significance		
Likelihood The chances of the impact occurring	Seriousness of the Impact Loss of life, property etc	Significance of the impact
L	M	M
H	H	H
L	L	M

Significance Rank

Very Low	Low	Medium	High	Very High
very low impact that does not require an adaptation response	low impact that can be dealt with as and when they happen or as budget allows	moderate impact that can be addressed by adaptation measures on a phased basis	high importance requiring immediate remedial action and further study	extreme impact requiring urgent action - to be given highest priority for adaptation

Valuation of impacts: The financial cost will vary in its importance whether an assessment is being undertaken for a poor rural village or a large urban centre for example. It can be difficult to estimate cost. For important impacts, a detailed cost-benefit assessment may be required. Estimates for damage and financial losses may be available for past disasters which can be used as cost coefficients.

The following is an example of the low and high end of the scale of seriousness for rural infrastructure:

Low significance:

- No loss of life.
- No injuries.
- No destruction of property.
- Some damage to property up to $500.
- Minimal loss of productivity and income up to a total of $1000 across the community.
- Minimal impediment to social/economic function of community (up to 1 day).

Very high significance:

- Severe loss of life.
- Many severe injuries.
- Destruction and damage to property above $100,000.
- Loss of productivity and income above $250,000 across the community.
- Impediment to social/economic function of community longer than 7 days.

Additional tools which can provide more information, rigor and scientific evidence inputs at various steps of the VA&A process are described in Appendix 8 with a detailed summary of economic analysis methods provided in Appendix 9.

The VA&A process set out in this guide can be conducted as a rapid assessment based mainly on expert and stakeholder judgements and knowledge through to a more rigorous and lengthy process requiring the establishment of a comprehensive scientific evidence base. It will depend on the size and importance of the projects and plans being considered, and on the funds and staff resources the sector has made available for the process.

A glossary of terms used in the vulnerability assessment and adaptation planning process appears as Appendix 10.

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8. APPENDICES
APPENDIX 1 BASELINE ASSESSMENT FIELD REPORT TEMPLATE

APPENDIX 1 BASELINE ASSESSMENT FIELD REPORT TEMPLATE

Purpose: To collect information to be able to undertake vulnerability assessment and adaptation planning.

NAME OF TARGET SYSTEM: ____

DISTRICT: ____
SECTOR: ____
DATE: ____
NAME: ____

1. **Provide short description of the system, its components and its location**

1. 2. 3.

2. **Describe the watershed context of the system**

Describe the location of the system within the watershed, the watershed condition and experience of past extreme events in the watershed (e.g. landslides and floods). Document with photographs and sketches any past or existing conditions which illustrate the problems that have arisen.

1. 2. 3.

3. **Describe the specific location**

Include the geographic and manmade features, any slopes, the vegetation, the soil type, proximity to any water bodies and any areas of instability.

1. 2. 3.

4. **Describe the condition of the system and its components**

Include description of signs of degradation and apparent causes/implications, and existing approaches to maintenance and repair.

1. 2. 3.

5. **Describe the design and form of any man-made components in the system**

Include description of current component/asset design and materials. Provide drawing and photographs of the asset design and condition.

1. 2. 3.

6. **Describe past extreme events and impacts on the System**

Include event dates, biophysical description of the events and impacts on the system and its components.

1. 2. 3.

7. **Describe past adaptation responses to the impacts of past extreme events**

Include description of adaptation responses, drawings if appropriate and a description of the success of the adaptation response.

1. 2. 3.

8. **Provide expert judgment of the design/form appropriateness of the man-made components to withstand extreme events**

1. 2. 3.

APPENDIX 2 VULNERABILITY ASSESSMENT FIELD REPORT TEMPLATE

APPENDIX 2 VULNERABILITY ASSESSMENT FIELD REPORT TEMPLATE

CLIMATE CHANGE THREATS

Change and shift in regular climate
Increase/decrease in temperature
Increase/decrease in precipitation
Increase/decrease in flow

Change and shift in events

Riverine flooding
Extreme localised pooling/flooding
Flash floods
Storms
Landslides
Droughts

DESCRIPTION OF THREATS circle relevant threat in list provided and describe how it relates to the target system and its components.

EXPOSURE Description	**SCORE**
SENSITIVITY Description	**SCORE**
IMPACT Description	**SCORE**
ADAPTIVE CAPACITY Description	**SCORE**
VULNERABILITY SCORE: Refer to guiding matrix to help identify the vulnerability score	

APPENDIX 3 VULNERABILITY ASSESSMENT MATRIX

APPENDIX 3. VULNERABILITY ASSESSMENT MATRIX

<table>
<tr><td colspan="8">System:
Major components:
1.
2.
3.
4.
5.</td></tr>
<tr><th>Threat</th><th>Interpretation of Threat</th><th>Exposure</th><th>Sensitivity</th><th>Impact</th><th>Impact Summary</th><th>Adaptive Capacity</th><th>Sensitivity</th></tr>
<tr><td>Change and shift in regular climate</td><td>Written description of how the threat relates to the system</td><td colspan="3">Refer to table</td><td>Written explanation of impact and explanation for score</td><td colspan="2">Refer to table</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="8">Change and shift in events</td></tr>
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</table>

1 *Include footnotes*
2
3
4

Summary

Threat	Exposure	Sensitivity	Impact Level	Adaptive Capacity	Vulnerability
1					
2					
3					

Concluding statement Command area least vulnerable to increased temperature and rainfall whilst intake most vulnerable to flash floods. The main canal is more vulnerable to sedimentation and landslide problems.

Notes on completing the VA matrix:

- It is important to be precise in the threats being considered? For example, with storms, will you need to notate what specific characteristics of storms? Wind, intense rainfall, lightning?
- In situations where the technical information is poor, you will need to rely more on expert judgement and knowledge.
- Similarly, local communities/user groups need to be consulted as an important source of experience and knowledge
- It is useful to conduct separate assessments for each of the main components as the impacts of various climate change threats may be distinctive. A more focussed assessment will allow more precise targeting of adaptation options and priorities.

APPENDIX 4 ADAPTATION PLANNING MATRIX

APPENDIX 4. ADAPTATION PLANNING MATRIX

Target Infrastructure System:

Description, including objectives and main elements.

Threats	Impacts	Significance			Adaptation Options	Priority Adaptation		
Insert all H and VH threats, first for the system as a whole and then for each of the H and VH components.	Insert the impacts recorded for the H and VH threats (only consider direct impacts)	Likelihood The chances of the impact occurring	Seriousness of the Impact Loss of life, property etc	Significance of the impact	Listing of the adaptation options in addressing each of the most significant impacts – focus on structural and bioengineering options	Feasibility cost, skills, staff, equipment	Effectiveness how well does it avoid, reduce or eliminate the threat	Priority

1 *Include footnotes*
2
3
4

APPENDIX 5 VULNERABILITY ASSESSMENT SCORING TOOLS

APPENDIX 5. VULNERABILITY ASSESSMENT SCORING TOOLS

Impact Scoring Matrix

Sensitivity of system to climate threat \ Exposure of system to climate threat	Very Low	Low	Medium	High	Very High
Very High	Medium	Medium	High	Very High	Very High
High	Low	Medium	Medium	High	Very High
Medium	Low	Medium	Medium	High	Very High
Low	Low	Low	Medium	Medium	High
Very Low	Very Low	Low	Low	Medium	High

Vulnerability Scoring Matrix

Adaptive Capacity \ Impact	Very Low Inconvenience (days)	Low Short disruption to system function (weeks)	Medium Medium disruption to system function (months)	High Long term damage to system, property (years)	Very High Loss of life, livelihood, or system integrity
Very Low Very limited institutional capacity and no financial resources	Medium	Medium	High	Very High	Very High
Low Limited institutional capacity and limited access to technical and financial resources	Low	Medium	Medium	High	Very High
Medium Growing institutional capacity and access to technical and financial resources	Low	Medium	Medium	High	Very High
High Sound institutional capacity and good access to technical and financial resources	Low	Low	Medium	Medium	High
Very High Exceptional institutional capacity and abundant access to technical and financial resources	Very Low	Low	Low	Medium	High

APPENDIX 6 VULNERABILITY ASSESSMENT REPORT CONTENTS DESCRIPTION

APPENDIX 6. VULNERABILITY ASSESSMENT REPORT CONTENTS DESCRIPTION

District assets/system priorities

- Short brief on the sector in the district – eg summarise the different types of infrastructure in the sector for the district and overall status
- Restate the criteria for identifying priority assets/systems for the vulnerability assessment
- Describe each priority system and its components

Vulnerability assessment method

- Short summary of method/process (no more than 1 page)
- Explain use of the method in this sector - for example the interpretation of the criteria for sensitivity, exposure, impact, and adaptive capacity
- Describe how the climate change threat profiles were interpreted for the sector – what projected changes are important for the sector in this district.

Vulnerability assessment results

- Present the results for each system in turn referring to the appended matrix.
- For each system and its components:
- Go through each step in the VA and draw out the most significant issues and interpretations.
- Pay special attention to describing the impacts column – both direct and indirect
- Draw together the results for each system (eg some components are more vulnerable than others and why)
- Repeat those analytical steps for each system

District vulnerability summary

- Provide a summary of the results (including a summary matrix - ie like irrigation project summary matrix)
- Describe which systems are the most vulnerable and why
- Describe the components of each asset/system which are most vulnerable and why
- Draw out the main lessons which can be applied to the different types of systems and different components
- Identify linkages with other sectors or geographic areas within the district

APPENDIX 7 MONITORING AND EVALUATION FRAMEWORK

APPENDIX 7. MONITORING AND EVALUATION FRAMEWORK

Adaptation Measure	Monitoring Focus	Frequency	Responsible?	Organisational Indicators	Technical indicators
Short-term Measures					
Long-term Adaptation Measures					

APPENDIX 8 TOOLS SUPPORTING THE VULNERABILITY ASSESSMENT AND ADAPTATION PROCESS

APPENDIX 8. TOOLS SUPPORTING THE VULNERABILITY ASSESSMENT AND ADAPTATION PROCESS

Key climate change vulnerability assessment and adaptation tools include:

Climate change downscaling and modelling: The downscaling of predicted climate change and Global Circulation Models (GCMs) enable spatial assessment to quantify future climate, using both statistical and dynamic approaches. Once MOSTE DHM capacities are in place, results from multiple GCMs and multiples downscaling techniques can be made available to infrastructure sectors on a regular and on-demand basis through the DHM portal and as a results of regular consultation with them.

Hydrological modelling: One of the most important effects of climate change is on hydrological processes and a reason why it is necessary to link projected climate changes with hydrological analysis.

Hydrological modelling is used in developing baselines and assessing changes in basic hydro-physical processes, including precipitation, hill slope run-off sub-surface infiltration and groundwater interactions, stream flow and water levels, and sediment transport. Catchment scale hydrological modelling includes flooding, water resource utilisation and land use change. The ICEM IWRM-model which DHM is being trained in using is a physical model which provides an advanced GIS-compatible framework for integrated modelling of water resources and water utilisation in both local and basin-wide scales.

Hydrodynamic modelling: Hydrodynamic modelling enables threats to be quantified. By running detailed 3-D models of lakes, river channels, and floodplains it is possible to quantify erosion, sediment dynamics, stratification of the water column, nutrient transport pathways, water quality, and productivity. Hydrodynamic modelling can also be applied to atmospheric environments for 3-D analysis of pollutant dispersion and emissions modelling.

GIS analysis: A range of GIS techniques are available for assessing the impacts of climate change and development, including zone of influence mapping, sectoral overlays, hot spot mapping and vegetation/land use identification mapping using satellite imagery. All modelling tool outputs and socio-economic analysis can be linked directly to GIS analysis making it a critical tool in the vulnerability assessment and adaptation process in this guide. For participants at all levels, GIS maps can bring to life the relationships between projected changes and infrastructure systems and areas and make the impact assessment process more credible.

Two important GIS tools for VA&AP tools are:

- Participatory mapping: When detailed hydrological modelling of past extreme events and of projected climate changes are not available, then past extreme events such as floods and landslides can be mapped with the input of local communities and local government experts who were present at the time. For example in June 2013, continuous rain in upper catchments of Nepal caused the water level in the Seti River east of the Mahakali to rise from 6.94 m to 11.56 m and 5.53 m to 12.81 m in the Karnali at Chisapani within a 24 hour period. The discharge in the Mahakali River rose from 139,000 to 440,716 cubic feet per second, causing river bank collapse and loss of life and property. Local residents and government officials have a vivid memory of depth, duration and extent of the flood waters and would be able to draw their memories on base maps. Those sketches can be digitised on GIS maps and then checked for accuracy through participatory exercises. Often the flood hot spot maps which result are more accurate than maps coming from detailed hydrological modelling. Hot spot maps based on past extreme events are a good foundation for understanding conditions with climate change.

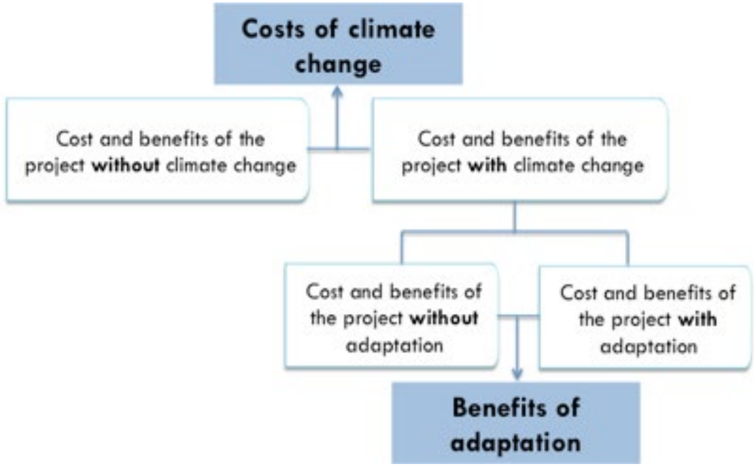
- A next participatory mapping step can be the definition of climate change hot spots. Simple calculations of increased water volume and flow can be made by considering projected rainfall increases and the size of catchments affecting the target area. That additional information can be discussed by participants who can then rank flood hot spots and interpret the effects of climate change projections on them.
- Hazard or hot spot mapping: The process of establishing geographically where and to what extent particular hazards such as floods and drought are likely to pose a threat to infrastructure and to local communities. Hazard mapping can be conducted as a participatory exercise and/or as an output of detailed modelling against various scenarios of climate change.

Macro-economic assessment and valuation: Macro-economic assessment examines the effects of climate change on individual sectors and the economy and cross sector implications of adaptation options. Valuation assesses impact costs and compares adaptation options through Cost-Benefit Analysis, Cost-Effectiveness Analysis, sensitivity analysis and trend analysis.

Economic assessments of climate change serve to justify appropriate adaptation response and identify the investment required to make adaptation effective. For infrastructure departments, economic assessments can cover two critical steps (Figure 12):

- Establishes the costs of climate change with respect to the infrastructure project: comparison of the net present value (NPV) of the project without climate change to the NPV for the project with climate change. The difference between the former and the latter represent the costs (or benefits) of climate change.
- Determining the benefits of adaptation: comparison between the NPV of the project with climate change, but without adaptation, and the NPV of the project with climate change and with adaptation.

Figure 12: Economic Assessment of Climate Change Impact and Adaptation



Integrated spatial assessment: Practical integrated assessment models such as Dyna-CLUE are designed for undertaking integrated spatial assessments and suited to focused climate change assessments for specific areas. The core of the model is spatial land use projections capable of integrating demand for different land uses, location conditions (including climate change) and policy scenarios. The model output can be read directly to assess the environmental consequences of the simulated changes. Integrated spatial models are using, for example, when considering alternative routing of a major road or the siting of water intakes, pump stations and canals in an irrigation scheme.

Impact assessment matrices: Impact assessment matrices for climate change allow the prioritising and weighting of options and recommendations. They are technical and capacity building tools that promote ownership by stakeholders of the process and its results.

Geotechnical surveys: Identifying where the likely points of failure are in different road routings, river bank dykes, water supply reservoirs and intakes for example may require field based geotechnical surveys. These are conducted by infrastructure sector engineer familiar with geotechnical issues of slope stability. In its simplest form it involves "walking the route" and recording observations in a field sheet against key variables such as existing road cross-section, natural slope condition and failures and existing earthworks (Figure 13). In a practical tool developed by ICEM, those field observations are scored allowing for the identification and mapping of hot spot zones along the route where failures are likely. In a road section of 10kms, for example, there may be five key points which need to be given priority for adaptation measures.

Monitoring and evaluation tools: M&E is critical to continuous learning and adjustment to adaptation measures based on performance and changing conditions. An M&E framework needs to be defined as part of the adaptation plan. The framework needs to identify responsibilities, frequency and indicators for measuring performance and identifying potential for failure.   Adaptation audits, conducted at regular intervals are needed to consolidate monitoring results and to propose further adaptation action and safeguards.

Community consultation tools: Consultation with affected communities and users of infrastructure is important in conducting vulnerability assessments and adaptation planning, especially in situations where the scientific and technical information is limited. The MOSTE manual on conducting Local Adaptation Plans of Action is a rich source of participatory and consultative tools which can be drawn from in conducting infrastructure VA&APs.

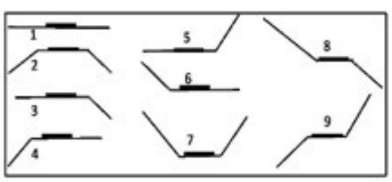
Walking The Route

Over the years, ICEM has conducted a number of slope stability assessments in various environments. Through this work, it has developed the following geotechnical survey data code for field assessments. The code outlines aspects to pay attention to when conducting a slope stability assessment. By following the code and noting each applicable aspect, you will ensure your slope stability assessment is detailed and thorough.

Geotechnical Survey Data Code

10. Structure
- 0 None
- 1 Pipe culvert
- 2 Box culvert
- 3 Bridge
- 4 Retaining wall

11. Cross-section



12. Ditch
- 0 Not required
- 1 Effective
- 2 Partially Blocked
- 3 Blocked
- 4 Missing

14. Access Condition
- 1 No issues
- 2 <10% access affected
- 3 10-25% access affected
- 4 25-50% access affected
- 5 >50% access affected

15. Water Channel
- 1 Gully/dry watercourse
- 2 Unlined stream
- 3 Lined ditch/stream
- 4 river

16. Earthwork Type
- 1 Cut
- 2 Embankment
- 3 Dumped spoil

17. Earthwork Angle
- 0 0
- 1 1-10
- 2 10-20
- 3 20-45
- 4 45-75
- 5 >75

18. Earthwork Height
- 0 0
- 1 0-3m
- 2 3-6m
- 3 6-12m
- 4 12-25m
- 5 >25m

19. Earthwork material
- 1 Silty clay
- 2 Silt
- 3 Clay
- 4

20. Earthwork Condition
- 0 No issues
- 1 Minor surface erosion
- 2 Minor slopeface failure
- 3 Severe gulleying
- 4 Moderate slope failure
- 5 Major slope failure

21. Vegetation
- 1 Bio-engineered slope
- 2 Mature trees/shrub/grass
- 3 Grass/shrubs
- 4 Sparse Grass/shrubs
- 5 Essentially none

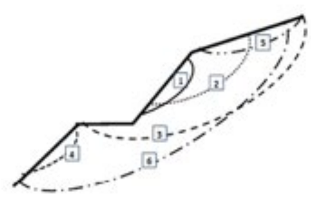
22. Natural Slope Length
- 1 <5m
- 2 5-20m
- 3 20-100m
- 4 100-500m
- 5 >500m

23. Natural Slope Angle
- 0 0
- 1 1-10
- 2 10-20
- 3 20-45
- 4 45-75
- 5 >75

24. Natural Vegetation
- 0 0
- 1 Mature trees/shrub/grass
- 2 Grass
- 3 Dry cultivation
- 4 Sparse Grass
- 5 Irrigated cultivation

25. Natural Slope Condition
- 0 No issues
- 1 Minor erosion
- 2 Minor surafce failures
- 3 Significant Upslope Instability
- 4 Significant Downslope Instability
- 5 Instability across alignment

26. Slope failure

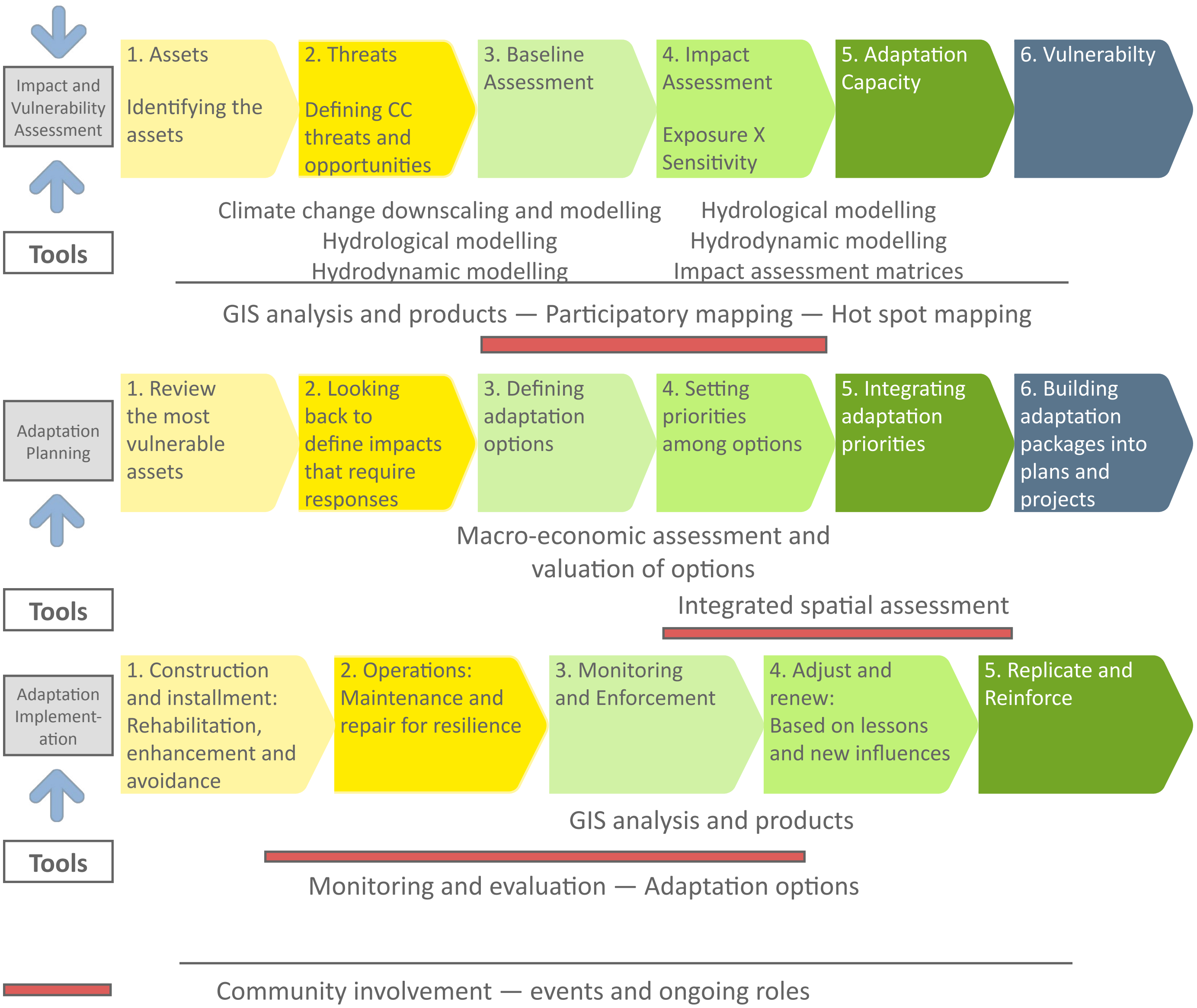


Notes legend
- Buildings
- Bridge
- C——C Culvert
- Road
- Ditch
- S——S Stream
- R——R River

Application of tools in the vulnerability assessment and adaptation process

The VA&AP and its appendices present a number of tools that can be applied in your vulnerability assessment process. These tools work together and in sequence to deliver the assessment and adaptation plan that most suits your needs.

The following diagram presents a summary of these tools in a potential sequence and in relationship to one another.



APPENDIX 9 APPROACH TO ECONOMIC ANALYSIS OF ADAPTATION OPTIONS

1 INTRODUCTION

Once a vulnerability assessment has been conducted for an asset or area and adaptation options have been identified, the options have to be appraised and prioritised. Economic assessments are useful in the process of evaluating and prioritising well-defined adaptation options using economic criteria.

Each adaptation option should be regarded as an investment. The economic analysis identifies which of the solutions proposed will create the highest benefit at reasonable costs and within budget. Decision-makers need to optimise budget allocation especially in situations of scarce resources (Noleppa et al., 2013).

The IPCC AR4 defines adaptation costs as "the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs," and defines benefits as "the avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures".
In order to evaluate the benefits of each proposed adaptation option, the impacts of climate change and quantify the costs of implementation of the options need to be assessed. Note that adaptation solutions usually will not completely eliminate impacts of climate change. It is important to take into account the costs of residual damage. Adaptation options which have the highest net benefits will be selected (UNFCCC, 2012).

When undertaking the economic assessments, planners need to consider the main purpose and core objectives of the adaptation options. For example, planners must decide if their objective is to:

- Minimise or avoid all or only part of the expected or observed impacts;
- Return levels of human well-being to pre-climate change levels;
- Maintain current levels of risk or as a minimum reduce them cost-effectively within agreed budgets or pre-defined acceptable levels.

In practice, objectives vary between regions, countries and communities, and trade-offs will need to be made between adopting all possible measures, and living with the risks (UNFCCC 2012).
There are three main techniques to be applied in the economic assessment of climate change adaptation options:

- Cost-benefit analysis (CBA);
- Cost-effectiveness analysis (CEA); and
- Multi-criteria analysis (MCA).

All three approaches are able to analyse and prioritise adaptation options (UNFCCC 2002, GSF 2011, Niang-Diop and Bosch 2011 and Noleppa et al., 2013).

According to Noleppa et al. (2013): "The objective often is to model climate change impacts and their associated costs and benefits. Such economic assessments are classified according to the type of model used. There are two main typologies. The first typology classifies models with respect to their economic (i.e. market and/or sector) coverage. Model in¬puts and outputs are mainly monetary values such as prices, revenues, rents, costs, etc. They are principally able to analyse costs and utilities (benefits) based on the standard concept of welfare economics. The second typology does not use a pure economic concept, but combines economics with physics and other sciences. Models first provide information on physical indicators (such as yields, occurrence of health problems, number of damages, etc.), which – endogenously or exogenously depending on the model – can often be related to monetary values. Important approaches are very specific physical models (such as a crop model) and so-called Ricardian models. These are generally not considered main econom¬ic approaches for the assessment of climate change adaptation options because they are not specifically designed to prioritise among alternative options."

Figure 1 – Selecting the suitable economic approach for assessing climate change adaptation options. Source: Noleppa et al (2013) and UNFCCC (2002) and Bosch (2011).

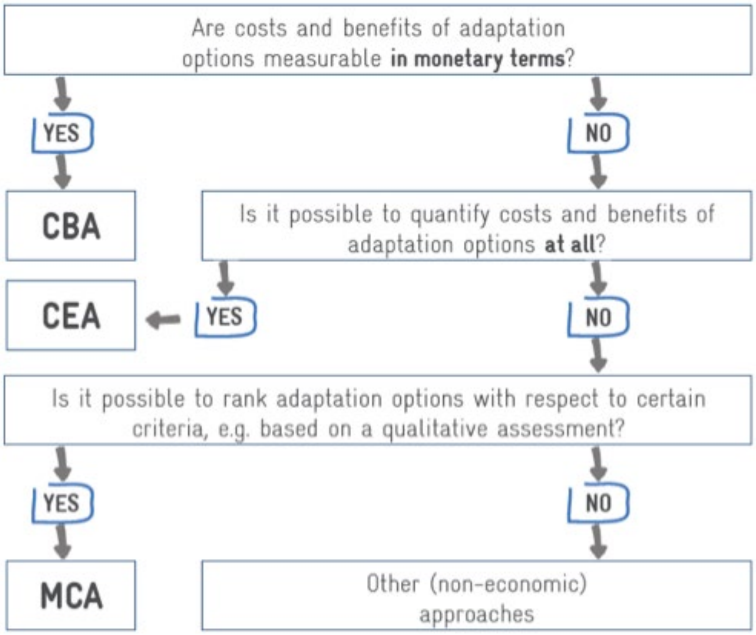


Figure 1 illustrates the decision process among the three main techniques mentioned above, the cost-benefit analysis (CBA), the cost-effectiveness analysis (CEA) and the multi-criteria analysis (MCA).

The three methods are presented in the following section alongside three case studies relative to the Asia-Pacific region. All case studies are taken directly from the UNFCCC work on impacts, vulnerability and adaptation to climate change (UNFCCC, 2012).

2 METHODS

2.1 COST-BENEFIT ANALYSIS (CBA)

CBA can rank activities, determine the optimal use of scarce resources in efficiency terms and, because CBA weighs costs against benefits, it determines whether benefits outweigh costs, allowing a decision on whether implementation is in the interest of the national or local economy. This clear “yes” or “no” answer, the fact that measures across sectors can be compared and that CBA can be used to optimise measures makes this technique superior to CEA and MCA (UNFCCC, 2002).

A drawback of CBA is that it requires that benefits are measurable and can be expressed in monetary terms and that the emphasis is on economic efficiency alone. If there is no market for the goods or services provided by the activity, often prices can be estimated in indirect ways.

The following are the main steps in assessing adaptation options using the CBA, as described in UNFCCC (2012):

- Establish a baseline. A baseline needs to be defined – ie the situation without the adaptation intervention being carried out - as well as the situation with successful implementation of the adaptation option to determine the costs and benefits by comparing the two. The baseline is not the same as the present situation – it requires defining and projecting a “without” situation.
- Quantify and aggregate the costs over specific time periods. Costs of an adaptation action include direct costs (e.g. investment and regulatory) and indirect costs (e.g. social welfare losses and transitional costs).
- Quantify and aggregate the benefits over specific time periods. Benefits of an adaptation intervention should include the avoided damages from climate change impacts and co-benefits, where relevant. If there is no market for the goods or services provided by the adaptation activity, benefits can be estimated in indirect ways through non- market-based approaches, such as contingent evaluation.
- Compare the aggregated costs and benefits. The bottom line for choosing an adaptation option is the comparison of the monetized elements of costs and benefits. The costs and benefits need to be discounted to properly calculate their present value. Adaptation planners can choose between three indicators of whether their options are efficient:
- The net present value (NPV) is the difference between the value of the benefits and the value of the costs, cal¬culated at their present value. The NPV should be greater than zero for an option to be acceptable. The better the eco¬nomic value of an adaptation measure is the larger the NPV becomes. However, a larger NPV does not neces¬sarily indicate higher efficiency.
- The benefit-cost ratio (BCR) is the ratio of the present value of the benefits to the present value of the costs. Benefits and costs are each discounted at a chosen discount rate. The benefit-cost ratio indicates the overall value for money of a project. If the ratio is greater than 1, the option is acceptable. The larger the BCR becomes, the bet¬ter the adaptation option is judged to be.

- The internal rate of return (IRR) can be considered the interest rate an adaptation option would generate for society. Technically speaking, the IRR is the discount rate at which the NPV becomes zero. Hence, a resulting IRR higher than the discount rate to be chosen is a good result.

Case study - NEPAL: assessing livelihood-centred disaster reduction measures using cost-benefit analysis (UNFCCC, 2012)

OVERVIEW

Practical Action undertook the "Mainstreaming Livelihood-Centred Approaches to Disaster Management" project in Nepal between 2007 and 2010. A CBA was undertaken following the implementation of the project, which focused on community-level project activities and did not include indirect long-term benefits that could arise.

Various adaptation measures were implemented, including investment in irrigation facilities to reduce drought sensitivity, installation of electrical fencing to reduce wildfire intrusion risks and flood risk reduction investments.

The costs included the direct project costs and the opportunity costs of human and material resources contributed by the target households and other local stakeholders. Benefits were measured by comparing the present value of real income gains to a 'no-project' baseline. The present value of the benefits was always higher than the present costs.

LESSONS LEARNED

In order to assess the benefits of reducing damage from future climate-related disasters as part of pre-project CBA assessment, it is advisable to obtain and record information on past disaster frequencies and associated damages as part of the baseline vulnerability assessment. Gaps in official statistics on this type of information are likely at the community level so that participatory methods will be required to obtain the necessary information.

2.2 COST-EFFECTIVENESS ANALYSIS (CEA)

If the benefits are difficult to express in monetary terms (as is the case, for instance, of human health, extreme weather events, and biodiversity and ecosystem services), CEA is the appropriate method to compare alternative measures to find out how an objective can be reached in the most cost-effective way. The objective needs to be sharply defined (UNFCCC, 2002).

The following are key concepts to bear in mind to properly conduct a CEA (Noleppa et al., 2013):

- Just as in a CBA, costs need to be quantified in monetary terms to conduct a CEA. The procedure is identical to the cost assessment used in a CBA.
- For a CEA, the unit in which benefits are measured has to be carefully defined (GSF, 2011). Examples are the number of animals preserved in a biodiversity programme or the area of pristine forest protected in a conservation programme.
- Quantifying (monetary) costs and (non-monetary) benefits means that the unit costs can be calculated as the ratio of total (discounted) costs to total benefits if – as in the case of a CBA – incremental costs and benefits (attainable by comparing a baseline scenario and one or more adaptation scenario(s)) rather than absolute costs and benefits are taken into consideration (GSF, 2011). The output indicator of a CEA is therefore also a Cost- Benefit-Ratio (CBR). The most cost-efficient option is the one with the lowest CBR, i.e. the lowest costs per unit of benefit. The inverse, a Benefit-Cost-Ration (BCR), can also be taken as an indicator; in such a case, the highest BCR directly indicates the most economically promising adaptation option.
- Beware that, if more than one type of benefit results from an adaptation option, a CEA can still be conducted as long as benefits can be expressed in the same unit in order to be compared and accumulated.

Case study - Pacific Islands: Assessing adaptation options for freshwater resources using cost-effectiveness analysis (UNFCCC, 2012)

OVERVIEW

As part of the Capacity Building to Enable the Development of Adaptation Measures in Pacific Island Countries project, adaptation measures were implemented at nine pilot sites on four islands in the Pacific (Cook Islands, Fiji, Samoa and Vanuatu) following intensive community consultations and CEAs. Communities in the pilot sites identified water resources as their greatest concern. Vulnerabilities were noted in terms of immediate quality and quantity, and in terms of the sustainability of supply. Fresh water resources are threatened by increasing salinity. Communities are suffering because inhabitants

have to spend a considerable amount of their day fetching water. Health problems are also increasing and agricultural yield is decreasing.
Among the options identified by the communities were the installation of desalinisation systems, rainwater harvesting, watershed protection measures, including contour farming, planting trees on hillsides, planting fruit trees within crop plots to provide shade for the plants or reinforcing salt tolerant vegetation buffers.

LESSONS LEARNED

All three communities selected rainwater harvesting as their preferred adaptation option. It was deemed to be the most cost-effective option (i.e. yielding the desired quantity and quality of water at the least cost). In addition, rainwater harvesting was determined to be the most practical, easily implemented, and sustainable measure. Other measures were either too expensive, such as desalination systems, or did not promise the desired quality and quantity of water, such as watershed protection measures.

2.3 MULTI-CRITERIA ANALYSIS (MCA)

When benefits cannot be measured quantitatively or when multiple diverse benefits cannot be aggregated, a Multi-Criteria Analysis (MCA) can be used by assessing the different adaptation options against a number of criteria. Similar to a CBA and CEA, an MCA is able to rank and thus prioritise among multiple adaptation options. However, contrary to a CBA, ranks resulting from an MCA are not based purely on economic calculations but on a qualitative assessment of criteria such as feasibility, cost effectiveness, co-benefits, ease of implementation, acceptability to local population and resources required (Noleppa et al. 2013)

The following are the steps in assessing adaptation options using MCA as described in UNFCCC (2012):

- **Agree on the decision criteria.** Each criterion needs to be described, including the unit and span of possible scores, so as to ensure that those involved in the assessment process have a shared understanding.
- **Score the performance of each adaptation option against each of the criteria.** Once this is completed, standardization is required in case scores of the various criteria differ in units (e.g. monetary or qualitative values) or spans (e.g. 1–5 or 0–100). Transformation of scores into similar units allows for effective comparison of the criteria.
- **Assign a weight to criteria to reflect priorities.** In case some criteria are perceived to be more important than others and the priorities are known, criteria can be assigned different weights, thus indicating their relative importance.
- **Rank the options.** A total score for each option is calculated by multiplying the standardized scores with their appropriate weight. Finally, weight- adjusted scores are aggregated and compared.

The main result of an MCA is a rank order of adaptation options and an appreciation of the weaknesses and strengths of the attributes of each of the options. An MCA can also be conducted in conjunction with other assessment approaches (CBA and CEA) to provide a more solid foundation for informed decision-making.

Case study - Bhutan: Assessing adaptation options using multi-criteria analysis (UNFCCC, 2012)

OVERVIEW

Bhutan assessed its vulnerability to climate change and possible adaptation options during the development of its National Adaptation Programme of Action (NAPA). A task force team consisting of representatives from key sectors including agriculture, biodiversity and forestry, natural disaster and infrastructure, health, and water resources identified and ranked possible priority adaptation projects using MCA.

In the beginning, a total of 17 adaptation options were identified based on the framework of climate-induced hazards. The nine shortlisted options were ranked based on the following four criteria (the first three constitute benefits and the last costs):

- Human life and health saved/protected by the intervention;
- Arable land with associated water supply (for agriculture/ livestock) and productive forest (for forestry/forest products collection) saved by the intervention;
- Essential infrastructure saved by the intervention such as existing and projected hydropower plants, communication systems, industrial complexes, cultural and religious sites and main tourist attractions;
- Estimated project cost.

Initially, the benefits of the different adaptation projects were scored to be able to rank them. Following that, the scores were standardised on a scale from 0 to 1 to proceed with the analysis and to allow costs to be included. The last step of the MCA was assigning weights to different benefits.

3 CONCLUSIONS

Adaptation planners should consider the strengths and weaknesses of the various economic assessment approaches for assessing adaptation options according to their objectives and circumstances. In some situations a number of approaches could be applied in a complementary fashion.

Table 1 clusters the different assessment approaches and their main strengths and weaknesses.

Table 1 – Strengths and weaknesses of the different approaches presented in this work

	Cost-Benefit Analysis	Cost-Effectiveness Analysis	Multi-Criteria Analysis
Description/ outputs	CBA assesses benefits and costs of adaptation options in monetary terms. Outputs include net present values, internal rates of return or benefit-cost ratios.	CEA identifies the least-cost option of reaching an identified target/ risk reduction level or the most effective option within available resources.	MCA assesses adaptation options against a number of criteria, which can be weighted, to arrive at an overall score.
Strengths	CBA can provide concrete quantitative justification for adaptation options rather than just relative information. It allows for a comparison between different aspects using a common metric (e.g. USD).	CEA can assess options, using units other than monetary units, thus it is good for effects that are difficult to value. It can be applied within the context of routine risks (e.g. health effects) as well as major climate risks.	MCA can consider monetised and non-monetised costs and benefits together. It also allows for considering a wide range of criteria including equity.
Weaknesses	CBA focuses on efficiency, when other criteria may be importan (e.g. uncertainty or equity). It has difficulties with non-monetised costs and benefits and may need a subjective input into the choice of discount rate.	CEA is unable to offer an absolute analysis or common metrics. It deals insufficiently with uncertainty or equity. The selection of thresholds or target risk levels is not always easy or objective.	Scoring and ranking of options in MCA is subjective and not easily comparable.

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APPENDIX 10 GLOSSARY

APPENDIX 10.
GLOSSARY

Adaptation – A process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented. Adaptation measures may be used to increase the resilience of infrastructure and other assets to withstand increasing intensity and frequency of climate events. Adaptation might include more regular and effective maintenance and protection measures, through to redesign and rerouting to avoid potential impacts. Adaptation may also include building the capacity of the people and institutions to prepare for and respond to the impacts of extreme events.

- Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation:
- Anticipatory adaptation – Adaptation that takes place before impacts of climate change are observed. Also referred to as proactive adaptation.
- Autonomous adaptation – Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation.
- Planned adaptation – Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve desired resilience.

Adaptation audit – Documenting adaptive measures taken by government or communities in response to past extreme events. Also, assessing their effectiveness as a guide to future adaptation on the principle of learning from the best of what is in place. Adaptation audits are normally conducted as part of the baseline assessment. They can also be conducted at regular intervals (say every 3 years) for measures put in place in response to climate change as part of adaptation monitoring and evaluation programs.

Adaptation impact assessment – Adaptation measures can have unwanted impacts on other geographic areas and on other sectors which undermine their resilience. Also, measures taken now might rule out future adaptation options. Adaptation impact assessment is conducted on the measures in adaptation plans to avoid or mitigate those unwanted effects.

Adaptation deficit – The adaptation deficit is those measures which need to be taken to address the known impacts from past climate variability and extreme events irrespective of climate change, but which would build resilience to future conditions. The adaptation deficit includes many actions required as basic ingredients of good development such as maintenance of drainage systems, effective sediment trapping in irrigation schemes and use of bioengineering methods to strengthen slopes and banks associated with roads and dykes.

Adaptive capacity – The ability to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. One way to enhance adaptation is by building 'adaptive capacity'.

Asset – A resource with economic value that an individual, community, corporation or country owns or controls with the expectation that it will provide future benefit. Assets include infrastructure or the basic equipment, utilities, productive enterprises, installations and services essential for the development, operation and growth of an organisation, city or community. In the context of adaptation planning, an asset is any piece of infrastructure or resource for which a sector department has responsibility for its construction and maintenance, and for ensuring its long term sustainability.

Baseline – The baseline is the state against which change is measured. It might be a 'current baseline', in which case it represents observable, present-day conditions. It might also be a 'future baseline', which is a projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines.
Basin – The drainage area of a stream, river or lake.

Capacity building – In the context of climate change, capacity building is developing the technical skills and institutional capabilities to enable active participation in all aspects of adaptation to, mitigation of, and research on climate change.
Climate – Climate in a narrow sense is usually defined as the 'average weather', or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The classical period of time is 30 years, as defined by the World Meteorological Organization (WMO).

Climate change – Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), which defines 'climate change' as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. See also climate variability.

Climate model – A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity (i.e., for any one component or combination of components a hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical, or biological processes are explicitly represented, or the level at which empirical parameterisations are involved. Coupled atmosphere/ocean/sea-ice General Circulation Models (AOGCMs) provide a comprehensive representation of the climate system. More complex models include active chemistry and biology. Climate models are applied, as a research tool, to study and simulate the climate, but also for operational purposes, including monthly, seasonal, and interannual climate prejections.

Climate forecast – A climate forecast is the result of an attempt to produce an estimate of the actual evolution of the climate in the future, e.g., at seasonal, interannual or long-term time scales. See also climate projection and climate change scenario.

Climate projection – The calculated response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based on simulations by climate models. Climate projections are distinguished from climate forecasts, in that the former critically depend on the emissions/concentration/radiative forcing scenario used, and therefore on highly uncertain assumptions of future socio-economic and technological development.

Climate change scenario – A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships and assumptions of radiative forcing, typically constructed for explicit use as input to climate change impact models. A 'climate change scenario' is the difference between a climate scenario and the current climate.

Climate sensitivity – The equilibrium temperature rise that would occur for a doubling of CO2 concentration above pre-industrial levels.

Climate threshold – The point at which external forcing of the climate system, such as the increasing atmospheric concentration of greenhouse gases, triggers a significant climatic or environmental event which is considered unalterable, or recoverable only on very long time-scales, such as widespread bleaching of corals or a collapse of oceanic circulation systems.

Climate variability – Climate variability refers to variations in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability). See also climate change.

Downscaling – A method that derives local- to regional-scale (10 to 100 km) information from larger-scale models or data analyses.

Drought – The phenomenon that exists when precipitation is significantly below normal recorded levels, causing serious hydrological imbalances that often adversely affect land resources and production systems.

Dyke – A human-made wall or embankment along a shore to prevent flooding of low-lying land.

Effectiveness – The effectiveness of a proposed adaptation action to address a potential impact can be measured by assessing whether it will eliminate the impact completely, whether it will reduce the impact and by how much and whether it will take some time to become effective.

Erosion – The process of removal and transport of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, winds and underground water.

Exposure – is a measure of the extent to which the asset is exposed to the potential threats or existing hazards. Exposure in the context of climate change is limited to potential climate threats. The exposure may depend upon the relevance of the threat (e.g. increase in temperature) to the type of asset, and the extent to which the threat will increase (e.g. in intensity and frequency)

Extreme weather event – An event that is rare within its statistical reference distribution at a particular place. Definitions of 'rare' vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. By definition, the characteristics of what is called 'extreme weather' may vary from place to place. Extreme weather events may typically include floods and droughts.

Feasibility – is a measure of how feasible an adaptation measure may be – whether it is technically feasible, whether the sufficient time and materials available to do the work, Cost – how expensive is the measure? Is government budget available? And the capacities of community and government.

Groyne – A low, narrow jetty, usually extending roughly perpendicular to the shoreline, designed to protect the shore from erosion by currents, tides or waves, by trapping sand for the purpose of replenishing or making a beach.

Hazard – A hazard is an existing source of danger that may cause harm, damage or loss, or poses a danger to a system vulnerable to the hazard. A hazard may be a static physical obstruction, such as a landslide, or it may be a temporary danger, such as strong winds from a storm. A hazard is different from a threat in that a threat is a potential future event, such as the threat of landslide posed by the combination of heavy rains and a steep, unstable slope.

Impact assessment – The practice of identifying and evaluating, in monetary and/or non-monetary terms, the effects of climate change on natural and human systems.

Impacts – The effects of climate change on natural and human systems or assets. Often, reference to impacts refers also to secondary and tertiary consequences. For example, climate change can result in less rainfall, which will inhibit crop growth. This is either because it means less water falling on plots, less groundwater recharge, or less water in streams from which water is taken to irrigate crops. The secondary consequence of this is less crop product, which can lead to economic difficulties or hunger. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts:

Potential impacts – all impacts that may occur given a projected change in climate, without considering adaptation.

Residual impacts – the impacts of climate change that would occur after adaptation.

Infrastructure – The basic equipment, utilities, productive enterprises, installations and services essential for the development,
operation and growth of an organisation, city or nation.

Integrated water resources management (IWRM) – The prevailing concept for water management, which, however, has not been defined unambiguously. IWRM is based on four principles that were formulated by the International Conference on Water and the Environment in Dublin, 1992: (1) fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment; (2) water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels; (3) women play a central part in the provision, management and safeguarding of water; (4) water has an economic value in all its competing uses and should be recognised as an economic good.

Landslide – A mass of material that has slipped downhill by gravity, often assisted by water when the material is saturated; the rapid movement of a mass of soil, rock or debris down a slope.

Likelihood – The likelihood of an occurrence, an outcome or a result, where this can be estimated probabilistically. In this context, the likelihood of an impact is a combination of the probability of climatic events happening and that these events will have the predicted impact.

Mitigation – An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks. The term mitigation in the climate change context should not be confused with the “mitigation measures” used to address environmental and social impacts of developments.

Projection – The potential evolution of a quality or set of quantities, often computed with the aid of a model. Projections are distinguished from predictions in order to emphasise that projections involve assumptions – concerning, for example, future socio-economic and technological developments, that may or may not be realised – and are therefore subject to substantial uncertainty. See also climate projection and climate prediction.

Resilience – The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.

Riparian – Relating to or living or located on the bank of a natural watercourse (such as a river) or sometimes of a lake or a tidewater.

Risk – The probability quantifiable damage, injury, liability, loss, or any other negative occurrence that is caused by a threat or hazard. The probability of something happening multiplied by the resulting cost or benefit if it does. Sometimes used interchangeably with “hazard” and “threats”, the risk can be reduced through adaptation and addressing the impacts, even if the threats of climate change and the hazards they bring remain the same.

Risk Management Framework – the overall system for managing the impacts resulting from climate change and extremes of climate involving identifying the climate threats to a structure or asset, assessing the vulnerability and potential impacts, and then developing adaptation options and plans for its protection.

Scenario – A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships in respect to climate. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a ‘narrative storyline’.

Scoping is a critical, early step in climate change impact and vulnerability assessment – and in the final preparation of an adaptation plan. The scoping process identifies the boundaries of the assessment and plan – in terms of its infrastructure focus, geographic area coverage and temporal dimensions. Assets and issues that are likely to be of most importance and relevance to the assessment are described and those that are of little concern are eliminated. In this way, the assessment focuses on the significant effects and time and money are not wasted on unnecessary investigations. The scoping process will involve round table consultations with local government sector experts and local leaders and effected communities. It based on an initial understanding of the effects of past extreme climate and hydrological events in the target areas.

Sensitivity – Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by more frequent flooding due to increased water flow and volume in rivers during extreme flood events).

Seriousness – the seriousness of an impact is a measure of what would happen if the impact occurred. This might include loss of life, the damage to the asset and how long it would take to repair and at what cost, the loss of the services provided by that asset, and the economic implications. (Loss of life, Loss of property – i.e. destruction of property, damage to property, Loss of productivity and income, Impeding of function). This can range from trivial (very low) to catastrophic (very high).

Significance – The extent to which something (the impact) matters; its importance. In a risk management framework the significance of the impact is assessed from a consideration of the likelihood that it may occur with the seriousness of the impact.

Stakeholder – A person or an organisation that has a legitimate interest in a project or entity, or would be affected by a particular action or policy.

Streamflow – Water flow within a river channel, for example, expressed in m3/s. A synonym for river discharge.

Surface runoff – The water that travels over the land surface to the nearest surface stream; runoff of a drainage basin that has not passed beneath the surface since precipitation.

Threat – something that may cause damage or harm (to the asset) in the future.

Threshold – The level of magnitude of a system process at which sudden or rapid change occurs. A point or level at which new properties emerge in an ecological, economic or other system, invalidating predictions based on mathematical relationships that apply at lower levels.

Uncertainty – An expression of the degree to which a value (e.g., the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g., a range of values calculated by various models) or by qualitative statements (e.g., reflecting the judgement of a team of experts).

Vulnerability – Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change (i.e. threats and hazards), including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.