MANAGING CLIMATE RISKS IN WETLANDS

A PRACTITIONER'S GUIDE

Ministry of Environment, Forest and Climate Change

IKI INTERNATIONAL CLIMATE INITIATIVE

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

of the Federal Republic of Germany

Wetlands International

As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

Published by
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn

Address
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Indo-German Biodiversity Programme (IGBP),
GIZ-India, A-2/18, Safdarjung Enclave, New Delhi - 110029, India

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Project Description
Wetlands Management for Biodiversity and Climate Protection
Indo-German Biodiversity Programme

Implementing Partners
Ministry of Environment, Forest and Climate Change
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Wetlands International South Asia, New Delhi

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Prepared by
International Centre for Environmental Management (ICEM), Regional Center for Development Cooperation (RCDC), M S Swaminathan Research Foundation (MSSRF) and DEVOPSYS

Suggested Citation
ICEM (2023). Managing Climate Risks in Wetlands – A Practitioner's Guide. Prepared for GIZ.

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Photo credits
Ritesh Kumar (cover page photo), GIZ/Geetha Nayak (page 4, 33, 39, 54), GIZ (page 6, 8, 44) and as specified against images.

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This project is part of the International Climate Initiative (IKI).

On behalf of
German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV).

New Delhi, 2023

MANAGING CLIMATE RISKS IN WETLANDS

A PRACTITIONER'S GUIDE

मंत्री
पर्यावरण, वन एवं जलवायु परिवर्तन
और
श्रम एवं रोज़गार
भारत सरकार

सत्यमेव जयते

MINISTER
ENVIRONMENT, FOREST AND CLIMATE CHANGE
AND
LABOUR AND EMPLOYMENT
GOVERNMENT OF INDIA

स्वच्छ भारत
एक कदम स्वच्छता की ओर

भूपेन्द्र यादव
BHUPENDER YADAV

आज़ादी का अमृत महोत्सव

MESSAGE

At a time when our world is witnessing a rise in global temperature, swift action is required to manage the associated loss and damage that is anticipated. It becomes imperative for all the countries and individuals to take account of the various climate risks that surround us as well as the opportunities to manage them. In the 75th year of independence, India demonstrated such an opportunity by bringing the network of its Ramsar wetland sites to an incredible 75, the highest in Asia. Not only does this foster a sense of commitment towards our natural heritage, it also sets an example for an ecosystem which is pivotal in regulating climate-altering emissions.

With Hon'ble Prime Minister Shri Narendra Modi's Mission LiFE (Lifestyle for Environment), India is moving to an improved climate future with mindful utilisation. Through this mission, we aim to remind our citizens and youth of their increasingly critical role in climate decisions and policy making, and that our country is endowed with rich biodiversity, and protecting its natural ecosystems is our vital defence against climate threats.

With the G20 Presidency for 2023, India wishes to set an example by embracing the spirit of *Vasudhaiva Kutumbakam*, symbolising unity and togetherness in our response towards pressing global threats. We have taken far-reaching initiatives in shaping the climate and energy transition agenda, through extensive leaps in renewable energy, e-mobility, ethanol blended fuels, and green hydrogen as an alternate energy source.

Following the Kunming-Montreal Global biodiversity framework, countries have agreed on the '30X30' targets to arrest and reverse global biodiversity loss. To complete this journey, however, it is integral to combine the agendas of habitat protection with climate mitigation and adaptation.

I congratulate the Wetlands Division, MoEF&CC for taking a significant step in this direction with this publication titled, 'Managing Climate Risks in Wetlands – A Practitioner's Guide.' I am confident that it will contribute substantially in mobilising peoples' expertise for these essential habitats and add to our mission of collective climate action under the motto of 'One earth, One family, One future.'

Date: 24 .01.2023

(Bhupender Yadav)

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आज़ादी का अमृत महोत्सव

G20 भारत 2023 INDIA
वसुधैव कुटुम्बकम्
ONE EARTH • ONE FAMILY • ONE FUTURE

सत्यमेव जयते

आहारशुद्धौ सत्त्वशुद्धिः

स्वच्छ भारत
एक कदम स्वच्छता की ओर

अश्विनी कुमार चौबे
Ashwini Kumar Choubey

राज्य मंत्री
पर्यावरण, वन एवं जलवायु परिवर्तन
उपभोक्ता मामले, खाद्य और सार्वजनिक वितरण
भारत सरकार
MINISTER OF STATE
ENVIRONMENT, FOREST AND CLIMATE CHANGE
CONSUMER AFFAIRS, FOOD & PUBLIC DISTRIBUTION
GOVERNMENT OF INDIA

Message

India is home to a rich variety of wetlands, ranging from mangroves and estuaries to oxbow lakes and salt flats. Not only are wetlands essential for water, food and energy security of the people, they provide habitat for birds and other wildlife, regulate water flows, protect us from floods and droughts and play a crucial role in mitigating climate change. Adding to the existing national schemes and missions, India is coming up with more ways to protect these ecosystems and proceed towards a more climate resilient future.

Hon'ble Prime Minister Shri Narendra Modi's Mission LiFE (Lifestyle for Environment) is one such mission that advocates for individual level lifestyle choices to ensure better sustainability of the natural resources. Through this mission we aim to remind our citizens and youth of their increasingly critical role in climate decisions and policy making.

Water is the lifeblood of our planet and wetlands are its kidneys.; they clean and purify the water we use for drinking, irrigation, and other purposes. Without them, life on earth would be impossible. They provide a natural habitat for fish, birds, amphibians, mammals, insects, and other living creatures. They also help to maintain water quality by filtering pollutants from the water.

That is why it is so important that we take steps to protect and preserve these ecosystems. We must all work together to protect these vital ecosystems for future generations. I urge all citizens to join me in supporting this initiative.

Another such mission 'Sahbhagita' launched by the Ministry of Environment, Forest and Climate Change (MoEF&CC) aims to promote 'all-of society' approach in the management of wetland ecosystems. In this age of globally rising climate risks, it is crucial to incorporate sectoral convergence to combat climate change.

To counter the rising challenges that climate change may bring, a technical book has been also developed by Ministry with under the 'Wetlands Management for Biodiversity and Climate Protection' project implemented by MoEF&CC and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH for IKI-BMUV. Project. The 'Managing Climate Risks in Wetlands – A Practitioner's Guide' provides an effective framework for our stakeholders to include climate risks in wetland management planning. I hope this handbook will be well utilised by the site managers, knowledge partners and State Wetland Authorities to enhance climate resilience within wetland management.

(Ashwini Kumar Choubey)

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लीना नन्दन
LEENA NANDAN

आज़ादी का अमृत महोत्सव

सत्यमेव जयते

सचिव
भारत सरकार
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE

MESSAGE

Despite India's low share of cumulative contribution to global GHG emissions, the country is committed to pursuing a climate conscious development pathway. At the 27th session of the Conference of Parties (CoP-27) to the UNFCCC, the Ministry of Environment, Forest & Climate Change, Govt. of India released India's long-term low carbon development strategy wherein wetland restoration was highlighted as a priority adaptation action.

With Asia's largest network of Ramsar Sites, India has demonstrated its commitment towards climate action and ecosystem management. India celebrates the immense biodiversity in these sites and beyond. Preparation of a framework which ensures that such gems of nature are protected and conserved, is a vital element of our development strategy which incorporates the core principle of Mission LiFE, namely, mindful utilisation of resources, with Ramsar's concept of wise use of wetlands.

The MoEF&CC has been implementing the National Plan for Conservation of Aquatic Ecosystems (NPCA) to assist state governments in preparing and implementing Integrated Management Plans for Wetlands. A diagnostic approach for developing such management plans has been prescribed by the Ministry through the Guidelines published in 2019. The 'Sahbhagita' Workshop held in May 2022 marked the 'whole of society' approach for wetland management. As climate change impacts our lives, and poses a threat to our natural habitats, we need to respond to it by incorporating climate resilience in all our management plans.

I extend my best wishes for the success of this publication, titled 'Managing Climate Risks in Wetlands – A Practitioner's Guide.' It is only through such knowledge sharing, that we can improve the capacities of our front-end site managers and empower wetland-dependent communities with methods to combat climate change. I am confident that the integrated ecosystem management approach arising out of all these initiatives, will add value to India's efforts for a climate-resilient future.

(Leena Nandan)

Dated: January 27, 2023.

प्रकृतिः रक्षति रक्षिता
Nature Protects if She is Protected

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Dr. SUJIT KUMAR BAJPAYEE
Joint Secretary

सत्यमेव जयते

भारत सरकार
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
Government of India
Ministry of Environment, Forest and Climate Change

Foreword

Wetlands are one of the most bio-diverse and productive ecosystems on the earth. These ecosystems protect us from disaster events, contribute to our food and water security and build our resilience to climate change. It should also be understood, however, that wetlands can act both a carbon sinks and carbon sources, depending on how they are managed. Given their combined importance and vulnerability with respect to climate change, it is essential for wetland managers to understand how climate risks affect their wetlands and plan appropriate adaptation and mitigation actions for managing them.

As party to the Ramsar Convention since 1982, and with a rich diversity of 75 Ramsar sites covering more than 13 lakhs hectares, India is among the frontrunners in wetland protection and conservation. We believe that to effectively address the challenges of habitat degradation and climate vulnerability, there is a need to enhance our perspective on ecosystem management and improve the capacities of the people who undertake said management at the grass-root level.

The Guidelines for National Plan for Conservation of Aquatic Ecosystems (NPCA) stipulate preparation of integrated management plans (IMP) based on systematic diagnosis of various wetland features and influencing factors including climate change. To improve the understanding and capacities of the people given responsibility under these rules, we must leave no stone unturned and provide the best knowledge resources to complement the laws and regulations.

For this reason, I commend this publication titled, 'Managing Climate Risks in Wetlands – A Practitioner's Guide,' developed under the 'Wetlands Management for Biodiversity and Climate Protection' project implemented by the Ministry of Environment, Forest and Climate Change and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, India.

With a simple and flexible process accommodating both scientific inputs and community experience, this guidance document will be a practical and inclusive tool for site managers to identify and overcome climate risks in their respective wetland sites. It is my utmost hope that it is adopted by the different State Wetland Authorities as a guidance document to enhance the capacities of their site managers and other staff members, enabling them to assess and adapt their action plans in an accountable and climate-responsible manner.

27 January, 2023

(Sujit Kumar Bajpayee)

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आज़ादी का अमृत महोत्सव

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Abbreviations

AP	Adaptation Plan
CAM	Climate Change Adaptation and Mitigation Methodology
CBDRM	Community - Based Disaster Risk Management
CC	Climate Change
CDTA	Capacity Development Technical Assistance
DRR	Disaster Risk Reduction
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
GCM	General Circulation Model
GEF	Global Environment Facility
GHGs	Green Houses Gases
GIS	Geographic Information System
GLOFs	Glacial Lake Outburst Floods
ICEM	International Centre for Environmental Management
IMP	Integrated Management Plan
IPCC	Intergovernmental Panel on Climate Change
KDCS	Knowledge Dissemination (or Development) and Communication Strategy
MoU	Memorandum of Understanding
MCCRMD	Mainstreaming Climate Change Risk Management in Development
M&M	Monitoring and Maintenance
MoEFCC	Ministry of Environment, Forest and Climate Change
NAPA	National Adaptation Programme of Action
NPC	National Planning Commission
O&M	Operation and Maintenance
SCCF	Special Climate Change Fund
TR	Technical Report
UNDP	United Nations Development Programme
VA & AP	Vulnerability Assessment and Adaptation Plan
VA	Vulnerability Assessment

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1 INTRODUCTION

Wetlands are among the most vulnerable ecosystems to climate change. On the other hand, they also offer solutions to address the impacts of the same. Some wetlands, like peatlands, act as carbon sinks, and their destruction can lead to the release of greenhouse gases. High-altitude wetlands provide baseflows for many rivers and act as buffers for glacial melts. Moreover, as natural sponges, wetlands enable slow absorption of large amounts of water, thus acting as flood and drought buffers. Along the coast, wetlands like mangroves act as physical buffers and limit damages from storms and cyclones. It is projected that changes in the climate will lead to increased temperatures, modified precipitation, raised sea levels, and increase in extreme climate events. Climate change also has a pronounced impact on hydrological regimes. Some wetlands, including coral reefs, mangroves and wetlands found in tropical forests, sub-arctic forests and arctic/alpine zones, are especially at risk. The role of Inland freshwater wetlands in flood buffering will become more important in areas where the frequency and intensity of extreme rainfall are predicted to increase. Erratic rainfall patterns will also affect the salinity and supply of sediments and nutrients to coastal wetlands such as deltas and estuaries. Higher water temperatures will alter water quality and worsen many forms of pollution. Integrating climate risks in wetlands management is, thus, vital and will play a critical role in mitigation and adaptation in a changing climate. The Ministry of Environment, Forest and Climate Change (MoEFCC) in partnership with Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH , India and Wetlands International South Asia have been implementing an International Climate Initiative (IKI) supported project, 'Wetlands management for biodiversity and climate protection', at four Ramsar Sites in India. The project has developed an assessment methodology for site-level climate risk assessment and demonstrated how climate risks could be integrated into the wetland management plan at the site level towards capturing climate co-benefits while maintaining the wise use approach of the Ramsar Convention on wetlands. The experience and lessons learnt have been consolidated into a publication 'Managing Climate Risks in Wetlands – A Practitioner's Guide', which will serve as an important capacity development tool for Wetland Managers.

2 PURPOSE OF THE GUIDE

This publication, 'Managing Climate Risks in Wetlands – A Practitioner's Guide', provides a practical approach to integrating climate change risks and adaptation options into the management of wetlands in India. The guide sets out a simple and flexible process with supporting tools that can accommodate varying inputs of scientific evidence, expert judgement, and community knowledge and experience. The method works as well in community-level meetings, with basic climate change information, as it does with rigorous scientific data and expert teams. It can be a rapid process exercised over a few days or extended over many weeks, supported by a comprehensive scientific evidence base.

The methodology includes various participatory elements. During its pilot testing, the staff and other stakeholders were closely involved in the vulnerability assessment process, validating and exploring the adaptation options through one-on-one meetings, focus group discussions and stakeholder workshops.

This process also had the benefit of field missions and stakeholder consultations conducted by the project team geared towards the important phases of the assessment and identification of adaptation measures, namely:

- Developing the baseline and identifying the target assets for vulnerability assessment
- Carrying out the vulnerability assessment to define the direct and indirect impacts
- Conducting the adaptation planning to identify and prioritise the adaptation options

In the management context, the climate risk assessment methodology assists in illustrating what aspects of wetland vulnerability can potentially be addressed through adaptation measures, promoting a strategic approach to management. The method provides a disciplined framework for systematically ordering and ranking the many climate change factors, their impacts and adaptation responses. It is best used as a priority-setting process for mainstreaming climate change in site management, even in situations of scarce resources and limited information. The process has three main phases: (1) vulnerability assessment, (2) adaptation planning and (3) adaptation implementation and adjustment (Figure 1).

Figure 1 *Vulnerability assessment and adaptation process*

3 INTEGRATING CLIMATE RISK ASSESSMENT IN INTEGRATED MANAGEMENT PLANNING PROCESS

The vulnerability assessment and adaptation planning methodology has three main phases as described above, with several steps in each, as shown in Figure 2:

1. Impact and vulnerability assessment
2. Adaptation planning
3. Adaptation implementation and feedback

The three phases and the steps involved have been explained in the following Chapters.

Figure 2 *Phases and steps of Climate Change Vulnerability Assessment and Adaptation Planning Methodology*

The vulnerability assessment and adaptation process are intended to be incorporated with integrated management planning (IMP) and budgeting cycles as prescribed by the National Plan for Conservation of Aquatic Ecosystems (NPCA) guidelines. Figure 3 describes the integration of steps of climate vulnerability assessment and adaptation planning into the IMP preparation process.

The integrated management plan preparation process for wetlands follows the diagnostic approach. The first part of the process is initiated with the characterisation of wetland features, including extent, catchment, hydrology, biodiversity, ecosystem services, livelihoods and governance. This would also include understanding past climate variability and extreme events. Status and trends for the priority features and target assets are assessed, including the identification of drivers of change. The assessment part of the process culminates with identifying and finalising threats posed by the adverse changes within the wetland complex. This would also include climate change impact and vulnerability assessment which follows a recognised pattern of assessing the exposure and sensitivities to climate change threats and the likely impacts that may result. When combined with the adaptive capacity of the target asset or system, their vulnerability can be analysed and ranked. This is followed by institutional analysis, which includes an evaluation of stakeholder and sectoral plans and current management practices with respect to their capacity to address the threats.

Management objectives for the Ramsar Site are formulated based on the threats, drivers of change, climate risk, and the assessment of capacity and training. Management objectives are then translated into concrete interventions for management at all scales and governance levels. This step entails a monitoring framework along with identifying priority areas for detailed scientific studies, detailing the parameters, indicators, frequency and the responsible institutions. The final two steps are – i) formulation of a detailed action plan and ii) development of a detailed institutional arrangement clearly defining roles and responsibilities, coordination mechanism and community engagement strategy to achieve the management objectives.

The aim is to build, over time, the vulnerability assessment and adaptation steps and tools into the regular review and revision process of the wetland management plans and the various development plans and actions of government and private sector organisations that affect the wetlands.

Integrating climate risk in wetland management planning

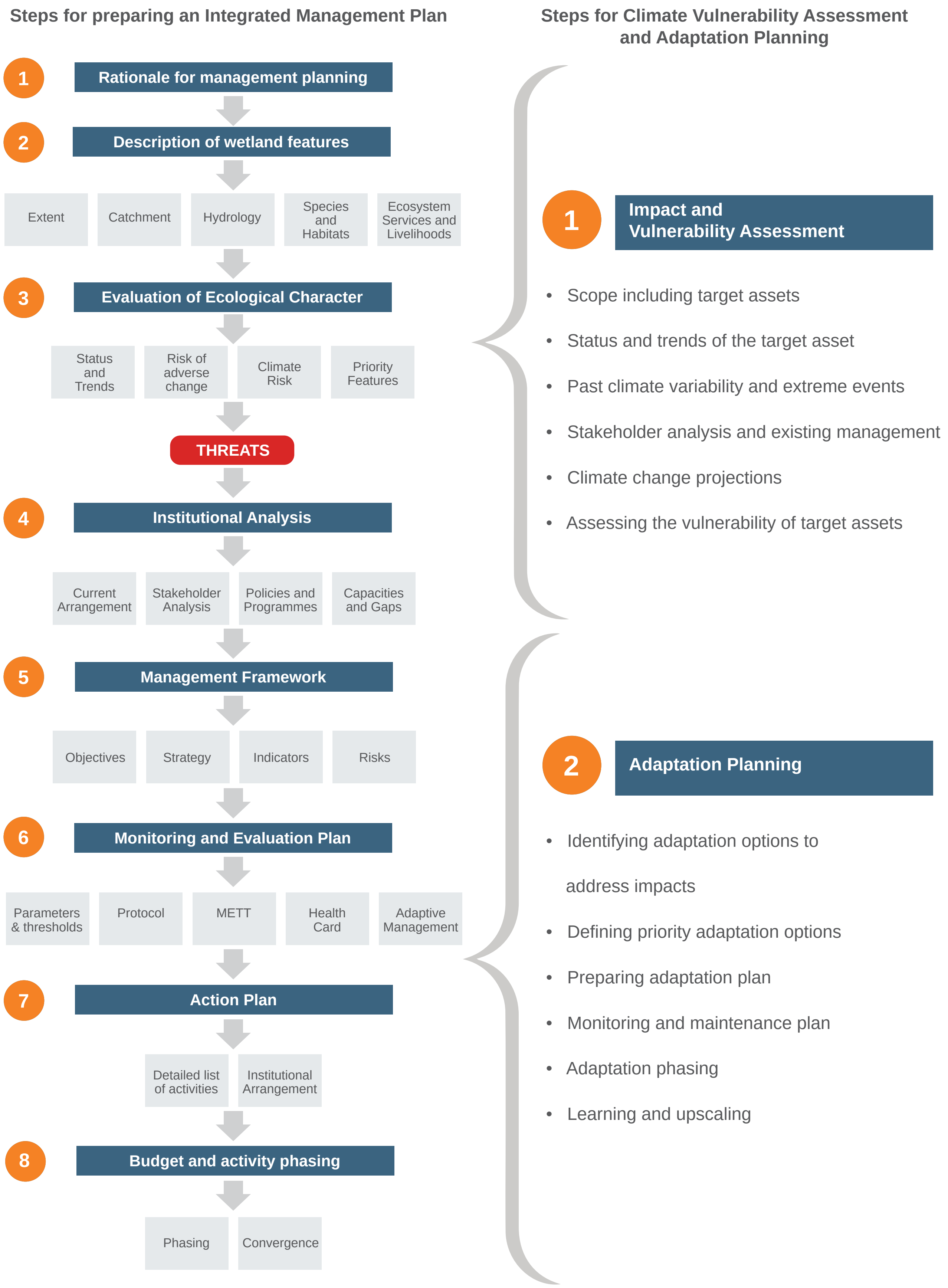


Figure 3 *Integrating climate risk in wetland management planning process*

4 IMPACT AND VULNERABILITY ASSESSMENT

The impact and vulnerability assessment phase has five main steps that help understand and document the impacts of climate change threats and opportunities on the various natural and built assets on the site (Figure 4). The term ‘impact’ is applied here because managers and local communities are familiar with the concept. In this case it means the potential effects of various climate change forces on the biodiversity and habitats in the wetland as well as on the livelihoods and economic activities and infrastructure within the site. The term ‘opportunities’ is added because climate changes may have positive as well as negative impacts.

Figure 4 shows the five main steps in the vulnerability assessment process: (1) scoping or identification of the main natural and built assets at the site; (2) the baseline assessment, which includes defining the various climate change projections with potential to influence the assets; (3) the impact assessment stage, which sets out the effects each climate change parameter could have on the assets; (4) assessing the capacity of the wetland ecosystem, management institutions and stakeholders to respond to the impacts and (5) the final scoring and ranking of the vulnerability.

1. Scoping	2. BASELINE ASSESSMENT		3. IMPACT ASSESSMENT	4. ASSESSING ADAPTIVE CAPACITY	5. SCORING VULNERABILITY
Assets Identifying the assets	**Threats** Defining the climate change threats and opportunities	**Baseline Assessment**	**Impact Assessment** Exposure Sensitivity	**Adaptation Capacity**	**Vulnerability** Impact/ Adaptation Capacity
Defining the asset inventory the main existing and planned infrastructure assets/systems in the area	Expressing clmate change conditions in terms relevant to the assets and target area covering threats and opportunities	Documenting past and existing conditions including climate variability and extreme events	Assessing the potential impacts of the threats and opportunities on the assets and area	Assessing the capacity of the management agencies and communities to respond and recover from the impacts	Establishing the relative level of vulnerability based on the impact and adaptive capacity

Figure 4 *The impact and vulnerability assessment process*

Figure 5 shows the Vulnerability Assessment (VA) process in more detail and the key factors involved. Also, it illustrates the baseline information and tools that contribute throughout the VA process.

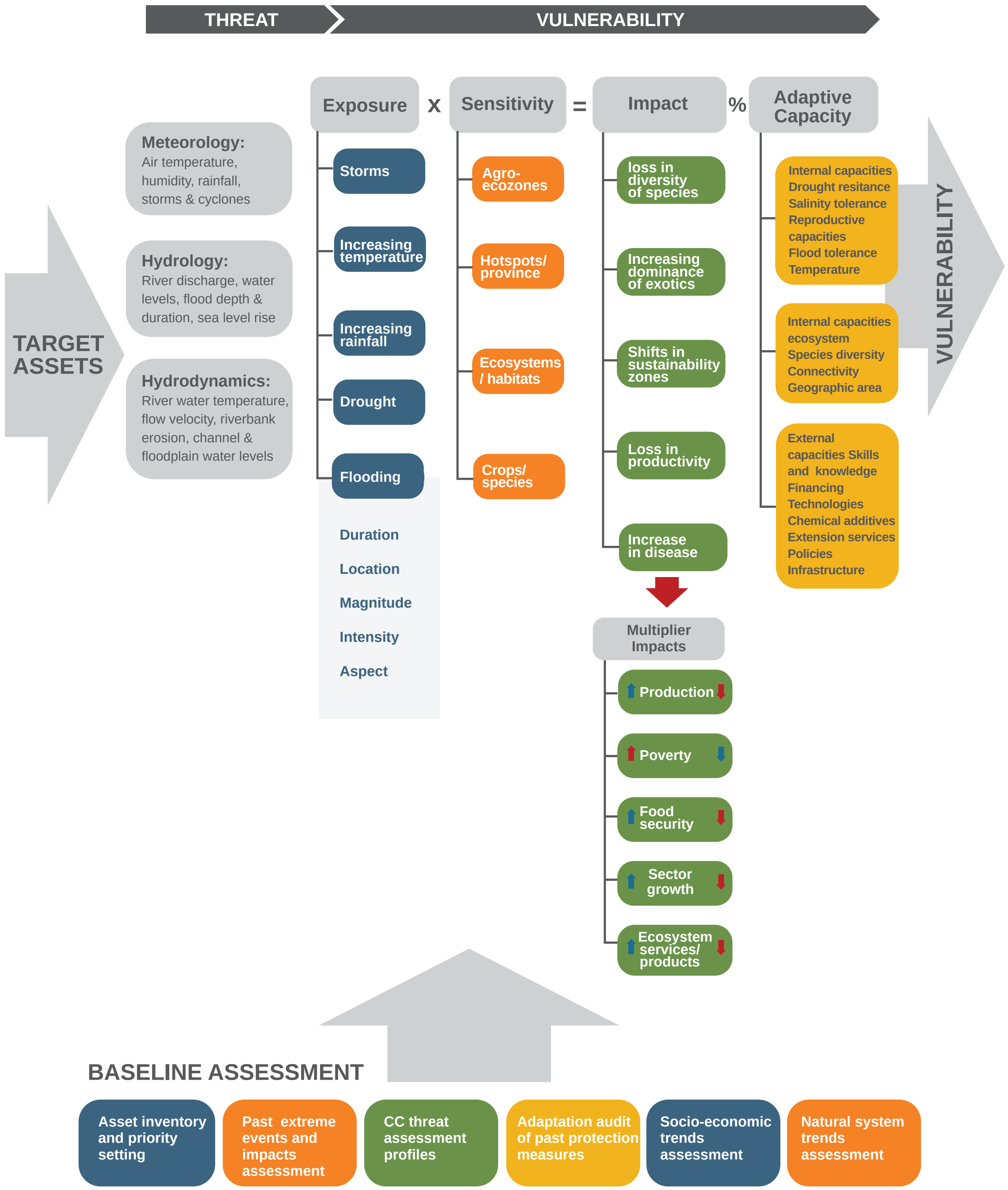


Figure 5 *Parameters and issues considered in the baseline and vulnerability assessment process*

The overall vulnerability assessment is recorded in summary form in a vulnerability assessment matrix. An example of a completed matrix (for the Bhitarkanika Ramsar Site) appears as Annex 2. Each of the steps is described in the sections to follow.

STEP 1 Determining the scope and target assets

The first step in any planning process is to set the boundaries or scope of what is being assessed. No single organisation can address everything. The scope will describe the limits of the planning task, including the time horizon, geographical area, assets to be covered and availability of resources for the assessment (e.g., money and human resources). This will involve making a basic model of wetland ecosystem functioning – linking ecosystem components, processes and ecosystem services within the wider river basin and coastal zone.

A Ramsar Site has clearly defined boundaries. But it is always important to assess the effects of climate change on wider areas such as the catchment or river basin, where activities external to the site can influence the assets within it. **The vulnerability assessment is best conducted for the entire Ramsar Site and for its wider catchment.** Also, it is necessary to identify individual assets of greatest concern so that they can be assessed individually. These assets are determined on the basis of ecological character evaluation – essentially, maintaining the ecological character is the very purpose of wetland management. These might include, for example, threatened and endangered species, critical habitats and keystone or framework species. They can include built assets that are important to Ramsar Site management or to local livelihoods. Keep in mind that the greater the number of assets identified is, the more time consuming will be the assessment.

Climate change risk outside the Ramsar Site may need to be carefully managed to reduce downstream or knock-on impacts within the site. Hence, it is likely that effective responses to impacts will go beyond the resources and mandate of the site management team and its management plan. They will involve actions by other agencies and communities of interest. That is a key reason why broad stakeholder engagement is needed from the earliest stages. A clear set of scoping statements should be developed and re-evaluated throughout the planning process. Scoping is mainly done upfront but tends to be an ongoing process of priority setting that can happen process of priority setting that can happen at various at various steps insteps in assessment and planning. Investigations at later stages may reveal that it is beneficial that it is beneficial to include to include additional additional factors orfactors or geographical areas or sectors into the scope. Or certain impacts and adaptation measures could be considered to be of low significance or priority and left out of further consideration.

Decisions on scope should be made against predefined criteria to identify the assets and areas as the main targets of VA

- **Natural systems -** e.g., endangered species, keystone species, critical habitats for breeding, food or shelter
- **Social systems and livelihoods -** e.g., livelihoods dependent on Ramsar Site resources, assets linked to economic activities such as ecotourism facilities, cultural sites or salt pans
- **Geographic areas -** e.g., Ramsar Site boundary, the wider catchment, coastal/marine areas influencing the site
- **Infrastructure systems -** e.g., main roads, bridges, hydropower dams, irrigation systems and reservoirs, river protection works, dykes, water supply and drainage systems

STEP 2 Conducting the baseline assessment

The baseline assessment of the target Ramsar Site assets needs to provide 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 should clearly state ongoing trends in ecological character (components, processes and services) and climate-induced changes in ecological character (ongoing and projected). The baseline describes the past and existing situation and trends and drivers affecting the target systems and analyses the changes to the system that will occur irrespective of climate change (Figure 6).

The baseline assessment also involves documenting the projected climate and hydrological changes that will affect the assets and the surrounding area. Usually, it requires field missions to relevant locations and consultations with stakeholders, including local government officers and affected communities. The baseline assessment field template to be completed by the vulnerability assessment and adaptation planning team appears as Annex 1.

TOOL

Baseline assessment field template

Sometimes information of past extreme events such as floods and droughts for example, or even design details of existing strategic infrastructure, is not available, and gathering local experiences, knowledge and judgements will be necessary.

Determining the climate change threats: The baseline assessment draws together information on past extreme events and climate variability impacting the assets and area. Often that information has not been well documented. So participatory mapping involving government and community members in the area can provide an accurate foundation for hotspot identification.

TOOL

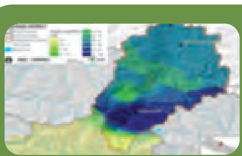
Participatory mapping of extreme events such as flooding and landslides

Asset inventory and priority setting

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

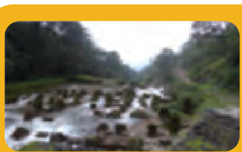
Past climate variability and extreme events

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



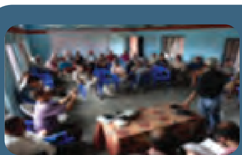
Climate change threat and opportunities profile

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



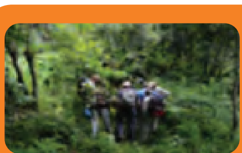
Adaptation audit of past protection measures

- Describe measures taken by the sector and / or community to learn from past extreme events
- Assess the effectiveness of those past "adaptation" measures



Socio-economic status and trends assessment

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



Natural system status and trends

- Describe the natural systems affecting the asset (eg. catchments and river banks)
- Describe the status and trends in those systems of relevance to the asset

***Figure 6** Baseline assessment components*

The baseline assessment also summarises climate change projections of relevance that may be available through official government reports and earlier studies. In some cases, there may be resources to conduct climate change downscaling and/or linked hydrological modelling for target catchments. In 2020, the Indian Ministry of Environment, Forest and Climate Change launched the India Climate Change Knowledge Portal, which vulnerability assessment teams can access[1].

The challenge is in communicating the climate and hydrological information in forms that are useful for specific sectors or communities and that match the target system. That requires an interactive process between national and local authorities and the sector experts to arrive at a set of climate change threat parameters that are best suited to their needs. The result is summarised in a climate change threat profile for the Ramsar Site and wider catchment.

Examples of climate change threats (and examples of linked impacts) that can be defined in the threat profile for the target area include the following:

TOOL

Climate change threat profile

- **Flooding (e.g., fluvial and flash floods) and increased precipitation:** threat of physical damage from intense flow and inundation, increased destabilisation of nearby land, erosion, landslides
- **Drought:** reduced water availability, sedimentation of canals, threat to productive crops, animal loss, drying/movement of soil/foundations leading to damaged structures, dust storms
- **Storms, strong winds, hail and lightning:** physical damage to natural and built assets (e.g., forests, houses, crops)
- **Heat waves:** crop losses, forest fires, damage to physical infrastructure through thermal expansion/cracking (e.g., pipes)
- **Low temperatures/frosts/cold snaps:** crop losses, animal losses, damage to built infrastructure (e.g., expansion of ice and loss of structural integrity)
- **Temperature changes:** loss of species unable to adapt to temperature changes
- **Glacial lake outburst floods (GLOFs):** GLOFs occur when increased rain, melting ice or an earthquake causes a glacial lake to burst and release its water in a very short period.

It is not necessary to cover all the climate change parameters but to focus on those which are most relevant for the target assets and area. Climate change may have beneficial impacts, for example, increased rainfall in the dry season at sites that suffer from droughts. The assessment team should ensure that parameters that might have positive effects are also considered.

STEP 3 Assessing the impacts of climate change on the assets

The method considers two important factors in assessing the impact of climate change on the target system and its components: *exposure* and *sensitivity.*

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 is best assessed by overlaying maps of past extremes such as floods and droughts and of projected climate changes on the area where the system is located or planned.

The exposure to a threat depends on:

- **The location** of the system with respect to the threat (e.g., distance from the flood zone or riverbank).
- **The threat intensity,** e.g., how deep and fast flowing the floodwater is.
- **Frequency,** e.g., the ‘return period’ of large, destructive floods – every 5 years, every 10 years, etc. and
- **Duration,** e.g., destructive flood threat lasts for 1 day, floodwaters remain for 5 days.

[1] https://www.cckpindia.nic.in/

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 events).

The rating system for exposure and other parameters uses a scoring from very low to very high and is applied on the basis of expert judgement drawing from the best available scientific and factual evidence and, where appropriate, community knowledge and experience (Figure 7).

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 and/or 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

Figure 7 *Exposure scoring protocol*

For example, the exposure of the mangroves to increased rainfall during the monsoon at the Bhitarkanika Ramsar Site is categorised as 'High' as the site is exposed to direct rainfall and to freshwater flowing in from the catchment. On the other hand, their exposure to reduced rainfall is categorised as 'Very High' as they will be directly exposed to reduced rainfall and reduced freshwater flows during the dry season.

Sensitivity: The next step in impact assessment is to rate the sensitivity, which is the degree to which the exposure to a threat will negatively affect the integrity or operation of the system. The Ramsar Site managers would have identified the target assets that will be subject to the vulnerability assessment and adaption planning process. Those assets are likely to include, for example, species, habitats, special areas such as breeding or feeding grounds, important infrastructure and cultural and livelihood features and structures.

Species' sensitivity can be used to prioritise conservation management and research needs. The sensitivity of species to climate change is influenced by many factors, including physiology, life-history traits, inter-specific relationships, habitat associations and relationships with disturbance regimes. A key driver of species' sensitivity is dependence on climate-sensitive habitats that are likely to be significantly altered. Judgements on sensitivity will depend largely on the expert knowledge and experience of the Ramsar Site managers, of specialists in relevant fields and on research findings.

Many habitats within Ramsar Sites are already suffering disturbance due to, for example, pollution, encroachment, over-exploitation and natural extreme events. Ecosystem responsiveness to disturbance is not rapid, and it may take an ecosystem many years to show significant recovery. The successional state of an ecosystem that has been disturbed influences its sensitivity to climate change. Disturbed ecosystems may be sensitive to even modest climatic changes. Identifying just undisturbed ecosystems as targets for the vulnerability assessment might thus lead to an underestimation of the impacts of climate change. The selected assets should include important habitats and ecosystems that are already environmentally challenged.

Broad questions that the Ramsar Site manager will need to address when considering the sensitivity of a species or its habitat include the following:

- Are currently threatened species and habitats in the site also sensitive to the projected effects of climate change?
- Does the current conservation status of the target species or habitat also reflect its degree of sensitivity to climate change?
- What are the specific aspects of climate change that are likely to contribute the most to its sensitivity?

A wetland feature sensitivity may be considered with respect to the extent to which it moves beyond its range of natural variation – for example, a freshwater wetland turning saline or a species moving beyond its known range.

Other more specific questions relate to the types of potential impacts, for example, direct impacts of temperature, rainfall or sea-level rises on assets, altered hydrology, changes in species interactions, climate change causing increased susceptibility to existing threats and climate change causing increases in threats.

The asset sensitivity of a Ramsar Site is likely to be influenced by the following:

- Species sensitivities, for example:
    - Species with very restricted geographic ranges
    - Small populations
    - Distinctive life cycle events (e.g., precise timing in flowering and fruiting, fish and bird migration, breeding)
    - Essential synergistic linkages with other species in the community likely to be affected
    - Body size (larger animals more affected by warming)
    - Genetic tolerance (e.g., sex differentiation sensitive to temperature)
- Specific location: asset proximity to most threatened areas, e.g., right on the riverbank or within the flood plain, with no natural barrier to the flood
- Geotechnical character: bank stability, soil condition, drainage, vegetation and existing stability measures. May require more formal geotechnical assessment or visual inspection
- Integrity of design: If the asset is infrastructure such as dykes or other features important to local livelihoods, such as crops or ponds, is it designed robustly and with features to mitigate against threats? For example, powered irrigation systems to protect crops against droughts; crop varieties resilient to frost/droughts; drainage around tourist hotels, roads and fields; and buildings raised above the flood line.
- Integrity of materials and construction: Is the asset built of strong, durable, appropriate materials, considering the expected threats? (e.g., unsealed/earth/dirt road or a paved/sealed road)

Considering these kinds of variables, the assessment team needs to rate system sensitivity from Very Low to Very High (Figure 8).

VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH
Species or habitat displays very low sensitivity to extremes in temperature and rainfall, or incidence of drought, flooding, storms and other climatic disturbances	Species or habitat displays low sensitivity to extremes in temperature and rainfall, or incidence of drought, flooding, storms and other climatic disturbances	Species or habitat displays medium sensitivity to extremes in temperature and rainfall, or incidence of drought, flooding, storms and other climatic disturbances	Species or habitat displays high sensitivity to extremes in temperature and rainfall, or incidence of drought, flooding, storms and other climatic disturbances	Species or habitat displays very high sensitivity to extremes in temperature and rainfall, or incidence of drought, flooding, storms and other climatic disturbances

Figure 8 *Sensitivity scoring protocol*

Impact: The product of exposure and sensitivity provides a measure of the potential impact of the threat on the system. The method provides a support tool for determining the impact rating – the impact scoring matrix. This is the most important stage of the vulnerability assessment, including detailing the potential impacts in the impacts' column of the VA matrix (Annex 2.).

TOOL - THE 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

The listed impacts provide the basis for defining the adaptation responses. Impacts are of two kinds:

(i) **Direct impacts,** which impinge on the system, for example, reducing an essential food source, and

(ii) **Indirect impacts** such as reduced carrying capacity for an endangered species. In the adaptation planning phase of the VA&A process, adaptation options need to be defined that address the most significant direct and indirect impacts.

STEP 4 Assessing the capacity to avoid or recover from the impacts

Adaptive Capacity: Once the impact assessment has been completed, the adaptive capacity of the target natural assets, managing organisation or community to prepare for and respond to the impacts needs to be assessed. Examples of factors to consider when determining adaptive capacity are listed in Table 1. It is not necessary to consider all of them. What needs to be addressed depends on the nature of the target system and the responsible organisations. When assessing the adaptation capacity of the responsible management authorities, including the on-site Ramsar management team, the most important factors are those that are of a cross-cutting nature – and those relating directly to the asset and its protection and rehabilitation, if needed.

Table 1 Factors to consider when assessing adaptation capacity

1. Cross-cutting factors	**2. Infrastructure**
• The range of available adaptation technologies such as bioengineering approaches • Management and response systems in place including policies and structures • Availability of relevant technical staff and knowledge • Availability of necessary equipment and suitable financial resources to support CC adaptation • Appropriate design standards that promote appropriate adaptation responses • Policy commitment to quick response availability and distribution of financial resources	• Availability of physical resources for repair/ reconstruction (e.g., materials and equipment) • Has the asset been regularly maintained • Are there backup systems in place (e.g., an alternative routing if a road or bridge fails) • Presence of other infrastructure negatively affecting the asset
3. Natural systems	**4. Social systems**
• Condition and stability of watershed affecting the asset • Riverbank and slope stability • Water quality (e.g., in the case of irrigation and water supply assets)	• Does the affected community have insurance and financial resources to respond? • Is a 'user group' established? • Do users have access to alternative services?

The example given here for rating adaptive capacity is of an organisation managing the Ramsar Site or of other sector agencies whose activities affect the Ramsar Site (Figure 9).

Figure 9 *Adaptive capacity scoring for external capacities*

Provide reasons for the scores

When deciding on ratings for exposure, sensitivity, impact and adaptive capacity, it is essential that the judgements be justified and explained in footnotes so that others reading the final vulnerability assessment matrix understand the reasoning behind the scores. Also, the reasons given for the exposure and sensitivity scores help complete the detailed impacts column of the matrix. They increase the authority and credibility of the final vulnerability ranking by making the process transparent.

STEP 5 Scoring and ranking vulnerability

If feasible, it is useful for the VA and adaption planning team to work on-site to complete an initial vulnerability assessment of the target system using the VA field form template that appears as Annex 5. That handwritten field form is then brought back to the workroom and through discussion with other sector technical specialists transferred into the formal vulnerability assessment matrix (Annex 2.). The formal matrix provides the framework for assessing a system and each of its target assets.

The final vulnerability score is determined by considering the impact and adaptation capacity together. The method provides a support tool for determining the vulnerability score – the vulnerability scoring matrix.

TOOL - VULNERABILITY SCORING MATRIX

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

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

5 CLIMATE RISK REDUCTION AND ADAPTATION PLANNING

Adaptation to climate change refers to actions taken by Ramsar Site managers, national and provincial government agencies, businesses and communities in response to the impacts of climate change. It can include actions taken to prevent, avoid or reduce the risks of those impacts (proactive adaptation) or taken in response to impacts as they happen (reactive adaptation). Most often, it will require building on the good work already being conducted to safeguard and manage the Ramsar Sites. It is useful to audit existing management responses to the current problems – many of these actions that are important ingredients in the existing management plans are good adaptation measures to the increasing stresses created by climate change.

Adaptation options in coastal, flood plain and mountainous wetlands will each include a mix of distinctive measures, and common measures. Many of the required measures will also need to be taken outside the Ramsar Site boundary, particularly in its catchment. This poses challenges for Ramsar Site managers, whose mandate is often restricted to the site boundaries. Even so, progressively, the Ramsar Site management plans need to identify influences outside the site boundaries that require adaptation actions by other stakeholders and then to seek government support promoting dialogue with the relevant public and private sectors. In coastal Ramsar Sites, necessary catchment adaptation options are likely to include, for example, the following:

Management plan components	**Examples of climate risk reduction and adaptation options for coastal wetlands**
Catchment and hydrology	• Preparation and implementation of regional/catchment sediment management plans • Maintenance of sediment transport and ecological flows • Rehabilitating watersheds and reducing erosion • Developing adaptive storm water management practices (e.g., promoting natural buffers, adequate culvert sizing)
Habitat and biodiversity	• Identifying and protecting ecologically significant ('critical') areas outside Ramsar Sites such as nursery grounds, spawning grounds and areas of high species diversity to allow the site to 'move'
Ecosystem services and livelihood	• Strictly control pollution levels from point and ambient sources, including the main polluters in the agriculture, domestic and industrial sectors.
Institutions and governance	• Regulations to allow coastal wetlands to migrate inland (e.g., through setbacks, density restrictions and land purchases) • Incorporate Ramsar Site and wetland protection into infrastructure planning (e.g., transportation planning, irrigation and energy facilities, sewer utilities).

These types of landscape or ecosystem-based adaptation measures will become increasingly essential in maintaining the health of downstream Ramsar Sites – but they are often beyond the mandate and capacities of the Ramsar Site managers to address. Yet, through wide-scale distribution of the climate change vulnerability assessments and adaptation plans for Ramsar Sites, the managers can seek to influence external adaptation actions. For coastal Ramsar Sites, many adaptation actions will fall within site manager's authority. Those actions will involve applying ecosystem approaches with various conventional engineering solutions. It is useful to keep in mind that various terms are now being used that have similar meanings. Some of the linked terms can be defined as follows. All are relevant to resilience building in Ramsar Sites.

- **Ecosystem-based approaches** encompass several related concepts, including nature-based solutions (NbS), green infrastructure (GI), blue infrastructure, bioengineering and ecosystem restoration. They all aim to enhance social and environmental resilience by restoring, maintaining and improving ecosystems and thus enhancing their services provided to living things and society, such as biodiversity conservation, water retention and prevention of soil erosion, floods and droughts.
- **Nature-based Solutions (NbS)** involve working with nature to address development challenges, providing benefits for human well-being and biodiversity. They involve the protection, restoration or management of natural and semi-natural ecosystems; sustainable management of aquatic systems and working lands such as croplands or forests; or creation of novel ecosystems in and around cities.
- **Green infrastructure** applies ecological principles and appropriate technology to enhance resilience and sustainability in development
- **Bioengineering** is the use of plants, local materials and landscaping as a replacement for or complement to conventional infrastructure

The overall goals of Ramsar wetland rehabilitation and maintenance are what count – and the various terms for the ways of doing these and their categorisation do not matter as much. To avoid confusion when communicating with stakeholders and those the Ramsar Site managers wish to influence, it is necessary to define the overall objective – i.e., biodiversity conservation – and then describe in more detail the measures that will achieve that with multiple environmental and social benefits.

Examples of the NbS and hybrid solutions that Ramsar Site managers can apply within the site boundary are:

- Preserving and restoring the structural complexity and biodiversity of vegetation in tidal marshes, seagrass meadows and mangroves.
- Prohibiting hard shore protection unless it is of direct benefit to maintaining Ramsar Site ecosystems.
- Promoting wetland accretion by using, for example, landscaping and contouring, native vegetation and natural materials such as geotextiles made from natural fibres, brush layers and live crib walls made of on-site fill material, timbers and layers of live branch cuttings.
- Removing hard protection or other barriers to tidal and riverine flows (e.g., riverine and tidal dyke removals).
- Trapping or adding sand through beach nourishment – the addition of sand to a shoreline to enhance or create a beach area for breeding turtles.

Not all hard infrastructure is a negative influence on ecosystem health in Ramsar Sites. It can be an essential ingredient in the adaptation response if implemented as hybrid measures with NbS. It can take the form of retrofitting and upgrading existing infrastructure such as roads and embankments, as well as anticipatory responses in which adaptation measures are built into new infrastructure linked, for example, to tourism facilities, temples and religious sites and drainage.

Adaptation planning involves developing a range of adaptation **options** for each of the main impacts of climate change 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 need to be made on what is feasible and necessary now and what can be left to subsequent planning cycles. Adaptation planning is all about priority setting and phasing of implementation. Adaption planning has three main steps -

(1) defining the options,

(2) prioritisation of options and

(3) preparation of adaptation plans and their integration into development plans and budgets (Figure 10).

6. Identifying adaptation options to address impacts			7. Defining the priority adaptation measures	8. Preparing adaptation plans and supporting measures to ensure implementation	
Review the vulnerable assets and components	Review the impacts which require adaptation responses	Define options for adapting to the impacts	Set priorities among the options	Prepare adaptation plans	Mainstream adaptation plans for implementation
Review the assets and components which have been assessed as most vulnerable and the threats they are facing.	Review all impacts for the system and its components and begin to group like impacts which could be addressed together.	Identifying a range of adaptation measures to address each impact or group of impacts. Options can relate to the system or individual components.	Identifying options or group of options that are most important, are feasible and bring most benefits.	Identifying linkages between options, their detailed actions and phasing then integrate into plan.	Define budgets and supporting measures and modify sector development and policies and plans as required.

Figure 10 *Adaptation planning process*

The aim of the adaptation planning process is to guide the preparation of an integrated adaptation plan to build resilience in the target system or area (i.e., to prepare a system or area wide adaptation plan and have it funded and supported). Like the vulnerability assessment phase, adaptation planning uses a matrix template supported by a number of tools to guide scoring. The same adaptation planning matrix template (Annex 4.) is used, whatever the target system or asset.

Ramsar Site managers need to consider the level of effort and justification that is required in setting adaptation priorities. It is feasible to go directly from the vulnerability assessment phase to defining an adaptation plan – i.e., without using the adaptation planning matrix. The matrix provides an additional discipline and systematic tool for identifying the most significant problems that need to be addressed and for prioritising adaptation responses when resources are scarce. Like the vulnerability assessment matrix, the adaptation planning matrix is a guide for discussion within the team and with stakeholders.

The final adaptation plan does not need to follow the matrix outcomes precisely – other factors may influence the adaptation priorities. Also, in some cases the matrix results may appear counterintuitive. If an adaptation measure is critical to the continued functioning of the Ramsar Site ecosystems but scores only medium priority for adaptation because of the high cost, then the final plan should override the matrix result and stress its importance.

STEP 6 Identifying adaptation options to address the impacts

Reviewing the threats and impacts: The adaptation planning phase of the VA&A method focuses on the most vulnerable assets and areas identified during the VA. The first step in completing the adaptation planning matrix is to review the key threats and impacts identified for the most vulnerable assets. The intention is to confirm the VA findings and ensure that all the most serious impacts are addressed. The VA matrix has been completed following a systematic and disciplined process – but still it is only a guide. Expert judgement and stakeholder consultation will be needed to highlight the impacts of most concerns and include them into the adaptation planning phase.

Identifying adaptation options: Adaptation options are shaped by the existing conditions at the target location, the climate change threats and the potential impacts on the assets being assessed. They are also influenced by the capacity of the system to recover from the impact.

It is important to draw from international, regional and local experience of what has worked in building resilience to extremes in the past. The main purpose of the adaptation audit conducted as part of the baseline assessment is to document the local experience in responding to past storms, landslides, floods, droughts and other extreme events and what has worked and what has not. Reviewing international experience can also expose Ramsar Site managers to new approaches, technologies and materials and even institutional arrangements and policies that have worked well in other countries. Inevitably, the resources needed to support adaptation are limited, and so sharp priorities must be set, and the approaches need to reflect the local capacities and resources. The approach to defining adaptation options is described in Box 1.

Threat → Impacts → Significance → Adaptation Options → Adaptation Priorities

ADAPTATION OPTIONS

- Draw from the adaptation audits conducted during the baseline assessment.
- Indicate what adjustments need to be made to existing practices and protection to more effectively respond to CC impacts.
- Consider adaptation options for the system as a whole and for each of the vulnerable components'.
- Consider new technologies and approaches

Adaptation Options

Listing of the adaptations options and addressing each of the most significant impacts

Adaptation options will relate to a hierarchy of integrated and mutually supportive measures addressing issues in the wider catchment down to very specific areas and supporting actions within the Ramsar Site.

AREA-WIDE ADAPTATION

A key strategy in defining the adaptation response is to look broadly at the wider catchment within which the Ramsar Site is located. That may mean, e.g., thinking through and defining the area wide approach to adaptation that this needed - and expanding the range of stakeholders who are engaged in the process. Setting a framework of broad principle for collaborative adaptation will help shape the roles and responsibilities for specific measures needed throughout the catchment. It will promote integration of adaptation measures across sectors and areas - and seek to avoid maladaptation that reduces downstream resilience. The aim will be to reduce local, non-climatic stressors such as eliminating aquatic/terrestrial invasive species, excessive nutrient and sediment loading, shoreline hardening, general habitat loss and encroachment.

RAMSAR SITE-WIDE ADAPTATION

Another response is to identify adaptation options for the entire Ramsar Site, with all its ecosystem complexity and diversity.

ASSET-SPECIFIC ADAPTATION

A third response is to determine the adaptation requirements for the high-priority assets identified in the vulnerability assessment process. Those measure can be very specific and relate to well-defined areas within the Ramsar Site and be species-specific.

SUPPORTING AND FACILITATING ADAPTATION MEASURES

The fourth response is often overlooked because it can be the most complex one and involves many authorities and stakeholders. To be effective, many of the measures defined for specific assets require supporting actions by other sectors, areas, resource managers and levels of government. It may involve establishing new decision making and management structures, for example, river basin committees or manufacturing coalitions. It may involve introducing new procedures for spatial planning and zoning with safeguards. It may involve more detailed modelling of hydrology to better inform the adaptation responses. A comprehensive adaptation plan for a Ramsar Site and its catchment need to be a structured combination of mutually reinforcing actions using natural, built, social, economic and institutional strengthening and innovations.

Box 1 *Defining adaptation options*

The consideration of supporting measures such as policy and institutional reforms can be ongoing as the more focussed adaptation planning moves forward – but a Ramsar Site VA & AP team should not be distracted from its focus, which is defining adaptation measures for the target system and its components. It is best to keep within the mandates and authorities of the immediate stakeholders. The VA & AP team should identify what these immediate stakeholders have the authority to do and to focus on defining adaptation actions within that mandate. Once this is done, the team can identify what other stakeholders can do to reinforce the immediate or core measures and to promote their sustainability and replication.

Table 2 illustrates categories of adaptation measures, some specific options and the key actors responsible for the implementation.

Table 2 *Adaptation options categories and examples*

Adaptation category	Specific measures	Main responsibility
Engineering measures	• Flood protection: dyke, upgrade drainage system, flood storage reservoir. Erosion protection: bridges, road culverts, etc. • Water storage structures (e.g., dams, tanks) for use during dry months • Reinforcing existing structures or building new ones to withstand severe storms and winds	From district - to national - level government. Can involve local user groups
Bioengineering measures	• Vegetation slope instability protection using grasses/shrubs/trees • Rock gabions using local materials • Large woody debris in streams to help slow the flow rate and create protected areas for vegetation to take hold; also creates habitat for aquatic animals • Rain gardens, bio-filters, vegetated swales for reducing/slowing down runoff and increasing infiltration rates	From local to national-level government. Also, local user groups and community-based organisations
Traditional local adaptation measures	• Bamboo stakes and vegetation riverbanks • Maintenance of traditional water sources and water user groups • Use local natural materials and designs in construction of houses, rock walls and wind breaks. • Re-vegetating foredunes and mud flats with local native species and re-establishing mangroves to combat erosion • Maintaining fish traps and reviving community gardens that diversify livelihood options • Traditional seed storage facilities	Landowners, user groups, local government level
Economic instruments	• Natural resource and land use taxes • Payments for ecosystem services • Grants and tax reductions • Conditions on licenses and permits	National or provincial government
Natural systems management	• Re-vegetation 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 droughts	National or provincial government with responsibilities delegated to user groups
Social responses	• Resettlement programmes • Livelihood and crop diversification • User groups for maintenance and management of facilities/resources • Seasonal and planned migration • Education and awareness programmes	Local communities, national or provincial government

Adaptation category	Specific measures	Main responsibility
Policies and regulation	• Zoning for development control, e.g., no major structures in flood plain or close to riverbanks • Regulatory requirements for structural integrity of buildings, material controls, floor height restrictions • Sector design standards (e.g., of culverts, materials, setbacks) • Urban zoning and safeguards • EIA and SEA provisions and tools that consider climate change	National or provincial government
Research and development	• Research into drought-/saline-tolerant crops. • New porous-surface materials to allow water penetration in urban areas • Tolerance levels and adaptive capacity in wild species and ecosystems	National or provincial government and institutes
Institutional responses	• Formation of local user groups for management and maintenance of infrastructure facilities • Structures for promoting partnerships with businesses and the community; programmes to integrate climate change within disaster risk management agencies • Creating an inter-agency network on climate change that encourages collaboration between organisations	National or provincial government

In most cases, an effective adaptation plan requires an integrated set of actions across several fields of management so that each reinforces the others. Also, it is useful to analyse how the action will modify vulnerability, by minimising exposure, reducing sensitivity or building adaptive capacity. Identifying adaptation options requires the involvement of a cross-sectoral group of specialists as well as stakeholders who are impacted. As in other phases of the process described in this guide, the extent and nature of consultation will depend on the availability of resources, the urgency for action and the level of decision making. In all cases, adaptation will require the action, cooperation and commitment of local affected groups so that their involvement at each VA & AP phase can be facilitated.

Level of detail in adaptation options

An adaptation measure, such as erosion protection, can be implemented in a variety of ways – from conventional engineering approaches that replace erodible surfaces with hard surfaces to integrated approaches that use bioengineering to protect from erosion and catchment management actions to reduce runoff. The detailed design of these options does not necessarily need to be defined when first identifying the adaptation measures. But it is important to be clear about the overall approach required from the earliest stages. This guide promotes the application of ecosystem-based approaches and nature-based measures so that bioengineering solutions are explored first or, in cases where hard engineering measures are needed, as an essential companion to meet the underlying biodiversity restoration and protection objectives.

VA & AP teams should apply that key principle of adaptation to first consider ways of using bioengineering and natural approaches to solving adaptation challenges before hard engineering options are considered. Adaptation should always contribute to ecological sustainability and to realising biodiversity gains while reducing climate change vulnerability. In general, it is best to consider integrated adaptation options that take wider ecological, social and economic factors into account as early as possible in the planning process. It is more difficult at later planning and implementation stages to achieve synergies and multiple benefits from the same action if they have not been considered early and planned for. Often these synergies can come at little or no additional cost when mutual benefits can be established.

STEP 7 Defining the priority adaptation measures

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 for future financing. Sharp priorities for action are required that are achievable with the available funds and that address vulnerabilities in the assets and systems of strategic importance to the Ramsar Site and to stakeholder communities.

Priority setting requires that some measures lay the foundation for future adaptation investments and facilitate future additions and modifications as the climate continues to change. An adaptation measure should not make future adaptation difficult or expensive. It should not rule out future adaption options or actions to build resilience to safeguard all species and habitats within the site.

STRATEGIC OPTIONS FOR ADAPTATION

To assist with setting priorities for adaptation in the case of infrastructure development, four strategic options can be defined:

(1) Invest now for lifetime adaptation
(2) Plan for phased adaptation over several management planning cycles
(3) Anticipate progressive modification as climate change impacts occur
(4) Build to repair when damage takes place

In most cases, **planning for a phased approach to adaptation over several management planning cycles is the** most effective approach. It may not be a matter of choosing between options but phasing them – some will need to be implemented before others, depending on the priority and feasibility. Still others will require further consultation and research. The four strategic options for adaptation can be best described for infrastructure such as dykes, roads or drainage systems within and outside the Ramsar Ste. Table 3 describes those options and their operational and financial implications. Similar constraints and opportunities relate to natural system adaptation options.

Adaptation approach	Description of adaptation approach	Expected financial implications
1. Build now for lifetime adaptation	• Build all adaptation measures immediately to last the project lifetime. • EIA and SEA provisions and tools that consider climate change	• Relatively high investment initially • No additional investment for subsequent adaptation required • Long-term security is dependent on actual climate change not exceeding the prediction
2. Plan for phased over lifetime	• Fully plan an upgrade programme to progressively adapt the design as climate changes occur. • Initial design provides functionality to adapt over life span.	• Medium-level initial investment • Investment required during asset life cycle • Implementation of project adaptation phases will occur as designed
3. Progressive modification to design	• Redesign and reconstruct as required in response to verified climate change. • Initial design may not provide functionality to adapt over life span. • Redesign and reconstruction required prior to damage or failure.	• Lower initial investment • Climate changes will force re-design costs and investments for reconstruction during asset life cycle to avoid catastrophic failure. • This is potentially an expensive approach.

Adaptation approach	Description of adaptation approach	Expected financial implications
4. Build to repair	• Accept there will be damage and repair as required. • Initial design does not incorporate adjustments to respond to climate change projections. • Should asset be damaged as a result, the asset manager accepts the damage and carries out repairs.	• Low initial investment • Likely financial loss due to damage of asset • Relatively high repair cost during life cycle, but overall may lead to lower whole--life cost if climate change does not cause substantial damage • This is the cheapest upfront option, but it comes with the largest risk and potential cost.

FEASIBILITY AND EFFECTIVENESS OF ADAPTATION ACTIONS

Once a list of adaptation options has been developed in response to an impact, priorities for action need to be set. It will not be feasible or necessary to implement all possible solutions. Some of the options may be mutually exclusive. Also, resource limits and policy or regulatory limits and standards may favour certain options over others.

The next step in the adaptation planning matrix (Annex 4) is to assess the feasibility and effectiveness of each adaptation option to arrive at a rating of priority.

FEASIBILITY OF AN ADAPTATION OPTION

The assessment of feasibility determines to what extent each option can be accomplished or implemented. Factors influencing feasibility that need to be considered include the technical complexity, capacity of the Ramsar management team and user community and the cost:

(i) **Technical complexity and demands:** When addressing this issue, the Ramsar VA & AP team should ask questions such as, Does the affected community or lead government agency have the knowledge and skills to use the technologies involved? Is the technology readily available? Are the materials available? Does it have high maintenance demands? Will it require investment in time and resources to understand how best it can be applied locally?

(ii) **Time to implement:** The commitment of time can be a critical factor in situations where past and existing extreme events have caused damage or threaten species and Ramsar Site facilities. Action is required now. Also, some options such as a riverbank dyke, may need to be fully in place to be effective – others can or need to be implemented over several years. For example, bioengineering measures can take several years of plant growth and adjustment to reach the needed levels of resilience and then to increase in strength over time.

(iii) **Capacity of local communities:** If local communities are an essential force in building, managing and monitoring the adaptation measures, many factors will need to be considered through consultation and surveying. Key factors include - who within the community will take the responsibility; will a special management or user group structure be needed; will the key actors be able to set aside livelihood activities to accommodate the new role; and will compensation be needed? It is not necessary for the adaptation team to resolve in detail all these issues and others relating to local community involvement, but it is important that some appreciation be gained on the level of effort that will be required to develop a consensus.

(iv) **Capacity of government:** In most cases, even for national policies and agencies involved, local government will have a key role in adaptation management of Ramsar Sites, monitoring and repair. If responsibilities are devolved to a 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.

(v) Cost. Cost has been left for the last in this list because it can be a 'showstopper'. It can easily prevent action being taken, or sub-optimal adaptation strategies being pursued, especially when important options might require long-term commitment of funds to be disbursed on a phased basis. If the estimated cost of an option is high – and beyond existing budgets – the adaptation matrix may show it as very low priority – even if it is critical for the effective rehabilitation and health of the ecosystems or for the safety of affected communities. It is sometimes best not to consider cost at the feasibility stage in adaptation planning. Adequacy in budgets is all about priority setting in how to apply scarce resources - and those judgements can be left until the full integrated adaptation plans have been prepared as part of the overall Ramsar Site management plan.

The final ranking from very low to very high feasibility is made on the basis of the judgements of the team and/or consultations with stakeholders, drawing from the detailed information gathered during the baseline and impact assessment phase. The factors to be considered do not require detailed treatment or any form of cumulative scoring. It is a matter of discussion and then reaching consensus on the level of feasibility for each option, considering all things to the extent time permits. In a workshop situation, for example, feasibility and effectiveness can be defined through group sessions over a few hours, drawing from the baseline assessment, VA matrix and follow-up field visits.

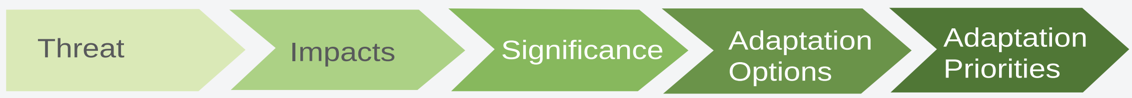
EFFECTIVENESS OF ADAPTATION OPTIONS

The next step in priority ranking is to determine the degree to which each adaptation option will be successful in producing a desired result – i.e., avoiding or reducing the negative impacts of climate change on the target assets and enhancing any benefits and opportunities that may arise. In other words, adaptation effectiveness is concerned with building resilience in the target assets and Ramsar Site.

Three appropriate questions to assess how effective an adaptation option will be at eliminating or reducing the impact are:

- Will it eliminate the impact?
- If not, by how much will it reduce the impact?
- Will it take some time to become effective (e.g., several years for the root system to establish in a bioengineered slope)?

These three questions are supported by a simple tool that can be used in finalising the score of each adaptation option, which ranges from very low to very high.



EFFECTIVENESS

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

	Very Low	Low	Medium	High	Very High
Can the impact be avoided completely?	Not at all		Partially		Yes
To what extent will it deal with the impact?	< 25%	25 - 50%	50 - 75%	75 - 90%	100%
How long will the adaptation measure last?	1 year	2 years	2 - 10 years	10 - 20 years	Permanent

Figure 11 *Assessing effectiveness in adaptation options*

Assessing the effectiveness of adaptation options can contribute to preparing indicators for a monitoring and evaluation framework that will be a section of the adaptation plan.

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

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

STEP 8 Preparing the adaptation plan and supporting measures

An adaptation plan sets out in an integrated way the adaptation priorities identified through the consultative planning process, their phasing and implementation arrangements. The plan addresses each of the target assets, the overall Ramsar Site and its catchment. There is no 'right' way to structure an adaptation plan. The scope of the plan - i.e., its coverage – should be defined as the first step in the VA&A – but it can be continually refined as the process unfolds. Ultimately, the plan must be integrated into the overall Ramsar Site management plan - and even picked up by relevant agencies with influential activities in the catchment.

An adaptation plan should detail the specific actions required to implement each measure and define the responsibilities and partnerships involved. There will be measures that are outside the ambit and capacity of a single local government agency and that require integration of all government responses. Where the need for collaborative implementation is identified, those measures will need to be discussed with other relevant agencies with a view to reaching agreements on collaborative arrangements. Box 2 describes possible ingredients of an adaptation plan.

An integrated adaptation plan for a Ramsar Site and its key assets and systems could include the following sections:

Overall description of the Ramsar Site, its main attributes and reasons for designation, its status and trends

The target assets - describe the target assets, their status and impact on their health. Describe the relative importance of each asset against Ramsar Site criteria

On-site adaptation measures: Provide detail of the priority adaptation measures, materials and technologies, approach to their management and how they support the overall conservation objectives of the Ramsar Site, for example:

- Habitat restoration and management
- Species support and management
- Livelihoods support and management
- Addressing sea level rise
- Protection against extreme events
- Drought and flood management

Off-site and supporting adaptation measure: Bring in supporting adaptation measures which may involve other agencies and levels of government - For example, economic incentives, reinforcing land use policies, and resettlement strategies – also, for example:

- Ensuring freshwater flows to the wetland
- Catchment rehabilitation and management
- Point source and ambient pollution control

Other development influences and their control: Describe other development influences which might affect adaptation plan implementation and identify desirable measures to reduce or control them – even if other agencies and sectors are involved.

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

Institutional arrangements and responsibilities: Detail how the adaptation plan will be implemented, the agencies involved, and any special structures which are needed such as local user committees or working groups.

Adaptation phasing: Set out the phasing of the adaptation measures and overall plan – Immediate (I), Short (S), Medium (M) or Long Term (LM) - For example 2, 5, 10 and 15 years or more. Identify the measures that need to be done urgently and those that need to be taken before others are possible. What measures require new technologies, capacities and structures and therefore may take longer to plan and implement.

Adaptation impact assessment: Conduct a rapid assessment of the impacts of the adaptation plan on the Ramsar Site and on other areas, sectors or stakeholders. Show how benefits will be enhanced and replicated and any negative effects (for example restrictions on uses and development) are to be minimised.

Reforms required for effective adaptation: Identify what adjustments are required to implement or replicate the adaptation measures – for example, revised guidelines, design standards, spatial planning and zoning. This section provides an opportunity to make recommendations for catchment wide reforms and for replication and upscaling.

A framework for monitoring and evaluating implementation of the adaptation plan. The framework should consider, for example:

- **Outcomes** such as pollution levels and standards reached; invasive species controlled, future desired state of the wetland achieved; unintended consequences (connectivity allowing for invasive species to move), effective stakeholder engagement
- **Scale** such as landscape and local/wetland context, scale of impact or target of adaptation – For example, species, wetland, watershed, and coastal littoral cell; temporal scale for results or outcomes

Stakeholder engagement in plan implementation, for example:

- What structures and processes are already in place for involving stakeholders
- Are there different platforms for different stakeholders – eg government, private sector and local communities

Box 2 *Infrastructure system adaptation plan ingredients*

The adaptation plan needs to record the adaptation measures proposed for the system and its components in a concise way as a short brief to guide a more detailed design and budgeting process as the plan is implemented.

6 IMPLEMENTATION OF CLIMATE RISK ADAPTATION MEASURES AND FEEDBACK

The adaptation planning and implementation process is cyclical and iterative in nature. It needs to be locked into and integrated with normal Ramsar Site management planning processes so that budgets and staff members are committed to adaptation on a regular basis and as a foundation requirement. This section of the guide – more so than the earlier parts – is a work in progress reflecting the state-of-the-art globally in adaptation implementation. Figure 12 describes the four main steps in adaptation implementation. It relates to various categories of adaptation measures that make up Ramsar Site managers' potential responses to climate change. These responses might include innovations in on-site infrastructure, nature-based measures, adjustments to species and ecosystem management strategies, adjustments to livelihoods, site zoning and safeguards, and a whole range of measures that are necessary outside the site but that influence conditions within it and involve external actors and activities.

9. Design and construction of adaptation measures	**10. Monitoring with regular maintenance and repair**	**11. Phasing adjustment and retrofitting**	**12. Audit, replicate and commit to adaptation**
Design may involve, for example, hot spot avoidance, bioengineering, rehabilitation of natural system, development controls and setting up community management and maintenance structures and processes	Investment in monitoring of landscape and infrastructure system for early warning of potential failure and of effectiveness of adaptation measures. A program of regular maintenance involving affected communities	Keep to planned phasing of adaptation measures based on latest CC information and lessons of implementation experience. Make adjustments, retrofit and invest in additional measures in response to changing conditions	Conduct adaptation audits and replicate what works well in other areas and for similar infrastructure systems. Ensure policies, procedures and capacities are in place to lock VA & A into the development planning cycle

Figure 12 *Adaptation implementation and feedback process*

STEP 9 Design and implementation of adaptation measures

The key consideration in a climate change adaptation approach is to ensure that the critical knowledge gained from the vulnerability assessment and adaptation planning process is incorporated into the preparation of an integrated management plan and is then delivered on the ground. Once adopted as a part of the overall Ramsar Site management plan, each adaptation measure will need to enter a detailed design phase, which can involve a range of soft and hard materials, bioengineering and conventional engineering and site-specific surveying and charting. Detailed designing will be needed, for example, for all adaptation measures aiming to achieve:

Habitat restoration (restoring a habitat to a pre-existing condition) or creating new wetland areas:

- Restoring native species
- Creating and maintaining diverse habitats supporting diverse species
- Protecting or re-establishing threatened or endangered species
- Increasing the extent of or improving wildlife habitat
- Increasing the extent of or improving plant habitat
- Restoring hydrologic and vegetative characteristics of altered grasslands, forests and riparian areas
- Requirements for removal of non-native plant or animal species.

River or land restoration:

- Replacing areas lost to man-made or naturally occurring activities or events
- Providing bank or shoreline protection
- Reducing loss of topsoil
- Facilitating on-site sediment disposal
- Facilitating fish-passage and habitat requirements (create, restore, enhance)
- Moderation of stream flows and flood protection
- Reducing peak flows
- Increasing the water retention and base flow
- Ensuring water treatment for instream flows, wastewater, and overland flows.
- Reducing the suspended sediment load
- Removing nutrients and/or pollutants and preventing and correcting pollution discharges

Each of these adaption measures – simple to much more complex – will require nature-based and engineered solutions and detailed designs and costings.

There is a need for strong links between the planning, design and implementation stages of adaptation. Limited communication between the team preparing the adaptation plan and the team involved in drawing up the detailed design of the adaptation measures, or between the design and implementation teams, can result in key objectives of the adaptation plan being misunderstood or overlooked. Strong linkages are especially important when changes are made to the original adaptation concept by design engineers or by contractors during construction.

The design of any infrastructure components in an adaptation plan, in particular, needs a clear understanding of the objectives of the adaptation plan and its measures and how it differs from a conventional infrastructure project through consideration of climate change impacts. To accomplish this understanding, technical personnel who have been part of the vulnerability assessment and adaptation planning of the project should be involved. They should be consulted regularly during the design and implementation stages.

STEP 10 Monitoring and maintenance

A key challenge in implementing adaptation measures is in ensuring they are properly installed and maintained. Effective monitoring programmes are an essential part of adaptation that require regular adjustment to changing circumstances. Monitoring identifies adaptation measures within the Ramsar Site – or in surrounding areas such as supporting slopes or upstream stability – that require maintenance, adjustments, rehabilitation or repair to maintain their resilience. In most countries, maintenance and repair following weathering or damage from extreme events is already a major budget item. Ramsar Site management is no exception – the costs of recovery from a major storm or flood event can absorb most of the site's annual budget. As far as possible, the M&M requirements of the adaptation measures should be well rooted in existing maintenance programmes and budgets at local and national levels.

Ensuring an effective M&M for adaptation will require capacity building in affected local communities and in responsible agencies. Local communities will need to be brought into the M&M process, especially in vulnerable areas where government capacity and resources are limited. Adaptation plans and their implementation should include provisions for:

(1) development of M&M processes and plans for each adaptation measure,
(2) capacity building of community members on M&M jointly with local NGOs and
(3) integration of specific M&M programmes into adaptation plans.

The knowledge and skills of partners involved in the M&M process – its purpose, methods and implementation steps need to be built, including coverage of the technical background information on the adaptation measures to be operated and maintained and, if possible, exchange visits to areas where similar approaches are being demonstrated/implemented.

The arrangements for M&M need to be spelt out in the adaptation plan, including guidance on which parts of the target system must be maintained, what exactly is to be done, how often M&M activities need to be conducted and who is responsible. It should also address how the M&M activities are financed.

Providing feedback on adaptation implementation: Monitoring the implementation and adjusting it based on the experience and new information is critical to taking a phased and systematic approach to adaptation. Monitoring requires a clear description of the objectives of the adaptation measures and how they link to the broader Ramsar Site management goals, i.e., how the adaptation measures contribute to the site's overarching conservation objectives. The key to effective monitoring at the local level is to keep the indicators of progress measurable and focussed on the specific adaptation measures and local conditions. The Indian Ministry of Environment, Forest and Climate Change, with support from GIZ and Wetlands International, has prepared a guide to wetland inventory assessment and monitoring that is an important resource for Ramsar Site managers in preparing an appropriate monitoring framework[2]. Long-term monitoring of key biophysical parameters in the wetlands and their catchments and adjacent seas is needed to provide time series data for developing benchmarks or baselines. Monitoring and adaptive management can use early warning systems, rapid assessment indicators and/or GIS-based approaches for detecting changes and the effect of the risk management options. Depending on the results from the monitoring studies, adaptive management actions will be taken to modify any of the above steps.

Adaptation monitoring indicators may be process-based (to measure progress in implementation) or outcome-based (to measure the effectiveness of the intervention). Developing indicators at the project level is relatively straightforward as the projects are undertaken within the context of overall Ramsar Site management, which may have well established monitoring and evaluation systems with proven indicators already in place. However, monitoring and evaluation on a broader scale, for instance, an entire catchment, is more complex as it requires strong coordination across sectors and levels and is more susceptible to external development factors.

[2] MoEFCC, 2020, https://indo-germanbiodiversity.com/pdf/publication/publication28-02-2020-1582881106.pdf

Practical difficulties in conducting a monitoring programme 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 and regular review (or auditing) of adaptation is one of the weakest areas of adaptation practice. The goal is to integrate adaptation monitoring with existing frameworks for development planning and implementation at sector and local levels.

STEP 11 Adaptation phasing, adjustment and retrofitting

Some adaptation measures identified in adaptation plans are scheduled for implementation at later phases of the Ramsar Site management cycle, depending on climate change projections. The need for those later measures should be kept under review on the basis of regular updating of climate change and hydrological information – and regular on-site inspections of asset and surrounding conditions. One tool described in Annex 6. (walking the route) is designed for that kind of site and asset inspection.

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

All Ramsar Site managers spend a large part of their budgets in maintenance and repair, most often when failures occur after 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, substantial investments are needed in regular updating of climate change downscaling, in hydrological modelling of catchments and in providing site managers with practical information that is tailored to their needs, on demand. The benefits of upgrading of the information systems and services will begin to show in more sensitive adaptation planning and design.

STEP 12 Learning and upscaling

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 - for example bioengineering techniques for slope and riverbank stabilisation. Additionally, they can be conducted every few years on adaptation approaches used in recent infrastructure development that might involve new technologies and materials. The aim is to build on and replicate the best examples of good adaptation across the expanding network of Ramsar Sites.

TOOL
Adaptation audits

Upscaling of good adaptation field practices means making the necessary reforms to policies, institutional arrangements and procedures at higher levels, which enables their systematic application within the Ramsar Site network and in the wider catchments.

Bioengineering and 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 – often using measures that are based on traditional knowledge and practice, as well as those that have been practiced by protected area managers for many decades often called bioengineering methods or more broadly green infrastructure. Green infrastructure is about changing the way 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. 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.

Already, India has a long history of using green infrastructure approaches in response to extreme conditions and natural disasters. There is much to be gained from documenting that experience and applying successful methods systematically.

Progressively, the line agencies working upstream of Ramsar Sites need to take on the responsibility for the review and adjustment of their own planning and management instruments to accommodate climate change adaptation on a regular and cyclical basis so that their actions lead to biodiversity gains and do not negatively affect the wetlands. For this, 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.

ANNEXURE 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 a 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 that illustrate the problems that have arisen.

1. 2. 3.

3. Description of specific location

Include the geographic and man-made features, any slopes, the vegetation, the soil type, proximity to any water bodies and any instabilities.

1. 2. 3.

4. Description of the condition of the system and its components

Include descriptions of signs of degradation and apparent causes/implications and existing approaches to maintenance and repair, e.g., evidence of increasing erosion and sedimentation, eutrophication and presence of invasive species.

1. 2. 3.

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

Include descriptions of the current component/asset design and materials. Provide drawings and photographs of the asset design and condition, e.g., dams, reservoirs, irrigation channels and culverts.

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 e.g., records of storms, floods, cyclones and storm surge, drought

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, e.g. construction of flood barriers and diversions, sea wall, riverbank strengthening, soil erosion and sediment management in the catchment, dredging of channels.

1. 2. 3.

8. Provide expert judgement of the design/form appropriateness of the man-made components to withstand extreme events, e.g., according to the opinion of the team, and in consultation with stakeholders have the listed measures to protect against extreme events been successful and have continued to provide the expected protection, or have they failed under pressure of extreme events.

1. 2. 3.

ANNEXURE 2: Vulnerability Assessment Matrix of Mangrove Habitats at Bhitarkanika

ASSET NAME: MANGROVE HABITATS

ASSET DESCRIPTION: Twenty-nine true mangrove species and 72 mangrove associates from different mangrove forest sites of the Bhitarkanika National Park[3]. The classified true mangroves have adaptation mechanisms to resist the physiologically dry surrounding environment, and they generally form pure stands in Bhitarkanika National Park. The Forest Survey of India-2013 report highlighted a drop in mangrove cover in the state by 9 km^2 since 2011, from 222 km^2 to 213 km^2. In Kendrapara district alone, where most of Bhitarkanika is located, the drop was 4 km^2. Since 2014, the Forest Department has been planting, and so the extent of mangrove cover is increasing, but the density is reducing. The baseline shows an increasing trend in salinity at all stations. The changes in freshwater flows from the catchment need to be clarified.

[3]Panda, M., Murthy, T.V.R., Samal, R.N., Lele, N., Pattnaik, A.K. and Chand, P.K., 2017. Diversity of true and mangrove associates of Bhitarkanika National Park, Odisha, India. International Journal of Advanced Research, 5(1), pp.1784–1789.

Threat category	Details of threat	Exposure	Sensitivity	Impact level	Impact summary	Adaptive capacity	Vulnerability
PRECIPITATION							
Increase in rainfall during monsoon (Jun-Oct)	Increase by 3.9% (i.e., 48.2 mm, from 1262.2 to 1310.4 mm) by the 2050s. A more significant increase in immediate upstream areas in the catchment (11.2% or 140 mm) This increase is likely to be concentrated in more intense events.	High[4]	Medium[5]	High	**Direct Impacts:[6]** • The increased rainfall in mangrove areas will have a beneficial impact growth and health, but this may be limited as the rainfall will be more intense. • With increased rainfall in the catchment, flows down the Brahmini and Baitarani rivers will increase in the monsoon, and this will tend to lead to a decreased salinity in creeks, with an increase in the growth and maintenance of the existing species mix. • Wetlands serve as a deterrent to the occurrence of floods. (+ve) • It is also associated with higher runoff and silt deposition, resulting in an accretion of land and associated mangrove migration to newly-built land. (+ve) • There will be submergence in the mangrove habitat. (-ve) • This may be affected by an increasing demand for irrigation and domestic water, which will reverse the benefits. • May lead to increase runoff and levels of pollution (including toxic effluents from industry and pesticides) in creeks. Increased flushing may reduce this threat to some extent. • The increasing sedimentation load could block some creeks and aggravate the salinity distribution. **Indirect impacts:** • The increased pollution load may be translocated in the food chain, affecting certain species and their biology (e.g., fertility) • An increase in the forest cover because of lower salinity and potential expansion of mud flats due to higher sediment loads the area • Erosion and waterlogging will increase, very few highlands will be left for wildlife such as deer, Wild Boars and reptiles. (-ve) • The survival of more saline-sensitive species will be enhanced. • The maintenance of a healthy mangrove system will lead to a potential increase in NTFP and livelihoods based on mangroves - honey, mats, etc. • Alternatively, the additional extreme rainfall events may lead to dying off of sensitive species (e.g., shrimps,	High[7]	Medium

[4]Mangroves are exposed to direct rainfall and to freshwater flowing in from the catchment.

[5]Mangrove growth and health is positively correlated with rainfall and the maintenance of an appropriate salinity balance. Growth and health also depend on the salinity of the surrounding waters. Different mangrove species have different tolerance to salinity changes.

[6]The overall increase in rainfall will have positive as well as negative potential effects on the Ramsar Site. The adaptation measures will primarily be focussed on reducing the negative effects.

[7]Mangroves will respond/adapt positively to increased monsoon rains. But the total flow of water in the site will depend on the upstream regulation, and the release regime depends on competing demands in the catchment. The potential for beneficial regulation leads to a high adaptive capacity. Mangroves will be directly exposed to decreased rainfall, and reduced freshwater flows during the dry season. The impact will depend upon the duration of the threat and periodicity during time

Threat category	Details of threat	Exposure	Sensitivity	Impact level	Impact summary	Adaptive capacity	Vulnerability
PRECIPITATION							
		High[4]	Medium[5]	High	crabs, frogs, fishes and crustaceans) due to oxic flushes of pollutants from sediments in catchment creeks + dilution effect of freshwater • Spatial distribution of pollutants to be mapped	High[7]	Medium
Decrease in rainfall during the dry seasons i.e., winter (Nov-Jan), summer (Feb-May)	Decrease by 8.2% (i.e., -13.3mm, from 167.0 to 153.7 mm), during the summer by 2050s. Slightly decrease by 5.5% (i.e., -3.7mm), during the winter	Very High[8]	High[9]	Very High	**Direct impacts:** • Mangroves are increasingly stressed during the dry seasons by increasing salinity in creeks. Growth and health during this season will be reduced. • Denudation or saline bank formations have been noticed in Bhitarkanika forest blocks, which is measured at 1700 acres. It said that denuded patches, spotted in Mathadia, could be over 30 acres in this block area. (-ve) • Poor rainfall can affect mangrove productivity, growth and survival through increasing salinity levels. (-ve) • Freshwater flows from the catchment will be reduced further, increasing the salinity and reducing the water quality[10] **Indirect impacts:** • Long-term stunting and die-back of mangroves • Drying up of wetlands and reduced water-holding capacity of the wetlands lead to drought. (-ve) • Shallow water bodies and wetlands are connected hydraulically to the surrounding unconfined aquifer systems. (-ve) • Loss of productivity of the mangrove habitat leads to reduced food availability for fishes and crocodiles, at the top of the food chain • Forest cover and species mix likely to shift – species with lower salt tolerance will be lost[11] • Degradation of the mangrove forest can release carbon stored in biomass and wetland soils[12]	Medium[13]	Very High

[8]Mangroves are very sensitive to increased aridity and salinity levels. Some mangrove species are more sensitive than others. The baseline shows a decrease in the area of dense mangroves.

[9]The Department of Water says there are no flow changes from the catchment, especially in the Khola canal, which is seen as a lifeline of freshwater flows to the park (80% comes from the Khola canal).

[10]The Department of Water says there are no flow changes from the catchment, especially in the Khola canal, which is seen as a lifeline of freshwater flows to the park (80% comes from the Khola canal).

[11]Most mangrove species have a salinity resistance that ranges from 5 ppt to 35 ppt. Only *Avicennia marina* can tolerate up to 70 ppt salinity.

[12]Trends of mangrove forests are increasing, but the quality and density need to be assessed.

[13]Most mangrove species have a salinity resistance that ranges from 5 ppt to 35 ppt. Only *Avicennia marina* can tolerate up to 70 ppt salinity. Trends of mangrove forests are increasing, but the quality and density need to be assessed. Mangroves have a natural adaptive capacity to dry season aridity and salinity involving reducing the growth, increasing salt excretion, shedding leaves, etc. But the upstream management of water flows down the river is constrained by other demands, reducing adaptive capacity.

Threat category	Details of threat	Exposure	Sensitivity	Impact level	Impact summary	Adaptive capacity	Vulnerability
TEMPERATURE							
Increase in temperature during the monsoon (Jun–Oct)	Average maximum temperature increase from 31.6 to 33.5°C (increasing by 1.9°C)	High	Medium	High	**Direct impacts:** • The mangroves will be less productive due to the increase in temperature.	Medium	High
Increase in temperature during summer (Feb–May)[14]	Average maximum temperature increase from 33.5 to 35.6°C (increasing by 2.1°C)	High	High	High	**Direct impacts:** • Average maximum temperature increase from 33.5 to 35.6°C (increasing by 2.1°C)	Medium	High
Increase in temperature during winter (Nov–Jan)	Winter will be warmer, with an increase of 2.0°C by the 2050s (from 27.6°C to 29.6°C) in average maximum temperature	Medium	Medium	Medium	**Direct impacts:** • The increase in temperature, as projected in the Brahmani and Baitarani basin can disrupt physiological processes, including a reduction in photosynthetic rates, decreasing leaf formation, which affects the net productivity. • The increase in temperature creates shifts in species compositions that, in turn, can affect the overall metabolism and productivity of the mangroves in the wetlands. This will impact the migratory birds and turtles. (-ve) • Prolonged dry periods could selectively eliminate aquatic plants (mangroves) that require wetter conditions. (-ve)	Medium	Medium
EXTREME EVENTS							
Sea level rise	Sea level rise projected at 0.5 m by 2040 for the Ramsar Site coastline[15]	Very High	Very High	Very High	**Direct impacts:** • Over-reduction in Ramsar Site area • Mangroves along the northern coastal section of the site, and along the central coastal strip, will be lost, amounting to approximately 20% of the forests.[16] • Also, fringing mangroves along creeks will be lost. • The mangrove forest species composition will change with the loss of saline-intolerant species. • Mangrove areas move inwards from the sea. • The mudflat area will be reduced – reducing crocodile habitats. • Loss of frontal mangroves will lead to a loss of Olive Ridley Turtle nesting beaches • The anthropogenic pressure on the Ramsar Site will be reduced as some of the villages will not exist due to submergence. (+ve)	Low	Very High

[14]This is an extreme season with limited rainfall and high temperatures – which tend to place stress on the forests and associated species. It is the flowering season for many plants preparing for propagation during the wet season, and so it is a sensitive period that will be affected by increasing temperatures.

[15]CWC, 2015. Operational Research to Support Mainstreaming Integrated Flood Management in India under Climate Change. Vol. 5b. Modelling Report Brahmani-Baitarani.

[16]The natural adaptation response of mangroves to sea level rise is to move inland – but in this case there is little area for potential mangrove colonisation. On the other hand, mangroves accumulate sediments from rivers and ocean currents and can raise the land level.

Threat category	Details of threat	Exposure	Sensitivity	Impact level	Impact summary	Adaptive capacity	Vulnerability
EXTREME EVENTS							
					Indirect impacts: • Reduced NTFP potential and associated livelihood benefits • Reduced habitat for crocodiles and other mangrove animals • Reduced attractiveness of the area for tourism • Reduced conservation values for some endangered species		
Cyclone	Very high risk of increased frequency of cyclones[17]	Very High	Very High	Very High	**Direct impacts:** • Already cyclones have seriously damaged the mangroves – and systems under stress tend not to recover. The anticipated increase in cyclone occurrence and severity will lead to forest losses. (-ve) **Indirect impacts:** • Damage to mangroves will impact the water-holding capacity of the wetland. (-ve)	Low	Very High
Storm surge	Moderate to high risk of up to 5-m storm surge[16]	High	High	High	**Direct impacts:** • Fringing mangroves along creeks will be lost. (-ve) • The mudflat area will be reduced - reducing crocodile habitats. (-ve)	Low	High

[17]Ahammed, K.B. and Pandey, A.C., 2020. Climate Change Impacts on Coastlines in Eastern Coast of India: A Systematic Approach for Monitoring and Management of Coastal Region.

ANNEXURE 3: Summary Vulnerability Scores for Bhitarkanika Mangroves

THREATS	Mangrove Habitat					Saltwater Crocodile					Catchment					Fisheries					Gahirmatha - Olive Ridley Sea Turtles					Tourism				
	Exp	Sen	Imp	Adc	Vul	Exp	Sen	Imp	Adc	Vul	Exp	Sen	Imp	Adc	Vul	Exp	Sen	Imp	Adc	Vul	Exp	Sen	Imp	Adc	Vul	Exp	Sen	Imp	Adc	Vul
PRECIPITATION																														
Increase of rainfall during monsoon (Jun - Oct)	H	M	H	H	M	H	L	M	VH	M	H	M	H	H	M	L	L	L	VH	L	VL	VL	VL	VH	VL	M	M	M	VH	L
Decrease of rainfall during dry season (Feb - May)	VH	H	VH	M	VH	M	M	M	M	M	H	H	H	M	H	H	H	H	L	H	L	M	M	L	M	VL	VL	VL	VH	VL
TEMPERATURE																														
Increase of temperature during monsoon (Jun - Oct)	H	M	H	M	H	M	H	H	H	M	M	H	M	M	M	L	M	M	M	M						VL	VL	VL	VH	VL
Increase of temperature during Summer/pre monsoon (Feb - May)	H	H	H	M	H	VH	H	VH	M	VH	H	H	H	M	H	M	H	M	M	M	M	H	H	M	H	M	M	M	H	M
Increase of temperature during the winter (Nov - Jan)	M	M	M	M	M	VL	VL	VL	H	VL	M	M	M	L	H	H	H	H	M	H	L	H	M	M	M	VL	VL	VL	VH	VL
EXTREME EVENTS																														
Sea level rise	VH	VH	VH	L	VH	VH	H	VH	L	VH						M	M	M	L	H	VH	VH	VH	VL	VH	VH	H	VH	L	VH
Cyclones	VH	VH	VH	L	VH	VH	L	H	H	M	H	H	H	L	H	H	M	H	L	H	VH	VH	VH	VL	VH	VH	H	VH	L	VH
Storm surge	H	H	H	L	H	H	VH	VH	VL	VH						M	M	M	L	H	H	H	H	L	H	H	H	H	M	VH

(Note: **Exp** = Exposure, **Sen** = Sensitivity, **Imp** = Impact, **Adc** = Adaptive Capacity, **Vul** = Vulnerability)

ANNEXURE 4: Adaptation Planning Matrix for Mangrove Habitats at Bhitarkanika

ASSET NAME: MANGROVE HABITATS

ASSET DESCRIPTION: Twenty-nine true mangrove species and 72 mangrove associates from different mangrove forest sites of the Bhitarkanika National Park. The classified true mangroves have adaptation mechanisms to resist the physiologically dry surrounding environment, and they generally form pure stands in Bhitarkanika National Park. The Forest Survey of India-2013 report highlighted a drop in mangrove cover in the State by nine square km over 2011-from 222 sq km to 213 sq km. In Kendrapara district alone, where most of Bhitarkanika is located, the drop was by 4 sq km. Since 2014 Forest Dept. has been planting, so the extent of mangrove cover is increasing, but density is reducing. The baseline shows a trend in salinity increasing at all stations. The changes in freshwater flows from the catchment needs to be clarified.

THREATS (high and very high)	IMPACTS (direct impacts)	ADAPTATION OPTIONS	PRIORITY ADAPTATION		
			Feasibility	Effectiveness	Priority
PRECIPITATION					
Decrease in rainfall during winter (Jan–Feb) - **High**	Mangroves are increasingly stressed during the dry season by increasing salinity in the creeks. Growth and health during this season will be reduced.	Appropriate water conservation, measures such as creating graded bunds, sub-surface dykes to be planned and facilitated by the Water Resources Department and the Forest, Environment and Climate Change Department.	Very High[18]	Very High[19]	Very High
		Release of water from the reservoir appropriately to manage the salinity in the creek: the Forest, Environment and Climate Change Department should coordinate with the Water Resources Department.	Medium[20]	Medium[21]	Medium
		Monitoring the water quality and salinity in the Ramsar Site, i.e., surface waters (including river, Khola creek, ponds, etc.) and groundwater at various locations, by the Water Resource Department, in collaboration with the Forest, Environment and Climate Change Department.	High	High	High
	Mangroves are increasingly stressed during the dry season by increasing salinity in the creeks. Growth and health during this season will be reduced.	A study on rainwater harvesting, recharge and the water balance and other hydrological studies should be conducted at the Bhitarkanika Ramsar Site. Water and soil conservation measures to be implemented in the catchment area	Very High[22]	Very High[23]	Very High

[18]Forest department of Odisha has the technical competency, a cost effective model and finance support could be supplemented from Environment & climate change action plan of the state government.

[19]This measure would dilute the salinity of underground water and provide protective moisture to the mangroves during the dry summer. This will provide a long term solution. Central Ground Water Board Government of India, manual on artificial recharge of ground water; September 2007; PP 96-98.

[20]The irrigation and hydropower projects are designed with priorities, supporting fisheries and the ecological services is internal and part of outcome, rather being exclusive

[21]Reservoir water sometime may not reach to mangrove area during the dry season as priority will be given to irrigation.

[22]Water and soil conservation technology is already adopted by the forest department in Odisha.

[23]Water and soil conservation will be the only sustainable measure for protection of mangrove.

THREATS (high and very high)	IMPACTS (direct impacts)	ADAPTATION OPTIONS	PRIORITY ADAPTATION		
			Feasibility	Effectiveness	Priority
PRECIPITATION					
	Denudation or saline blank formations has been noticed in Bhitarkanika forest blocks, which is measured at 1700 acres. It is said that the denuded patches, spotted in Mathadia, could be over 30 acres in this block area.	Plantation of appropriate mangrove species in the denuded patches on the basis of studies conducted by the Forest Department and monitoring data. The Forest, Environment and Climate Change Department needs to facilitate the necessary plantation.	**Very High[24]**	**Very High[25]**	**Very High**
TEMPERATURE					
Increase in temperature during the monsoon (Jun–Oct - **High**	The increase in temperature is likely to influence mangrove species' composition, phenology and photosynthesis productivity.	Mangrove species tolerant to increases in temperature to be promoted	**High**	**High**	**High**
Increase in temperature during summer / pre - monsoon (Feb–May) - **High**	The excessive salinity creates a bank formation over a period of time as the existing vegetation dies (studies and continuous monitoring of water salinity in and around the Bhitarkanika Ramsar Site are recommended).	Recharge aquifer with rainwater in the mangrove forest area – measures such as earthen bunds, percolation ponds, sub-surface dykes and other appropriate technologies are to be implemented by the Forest, Environment and Climate Change Department.	**High**	**High**	**High**
		Release of water from reservoir appropriately to manage the salinity in the Khola creek – the Water Resources Department.	Medium	Medium	Medium
		Monitoring the water salinity in the Ramsar Site area	**High**	**High**	**High**
		Plantation of *Avicennia alba/officinalis*, which are highly salinity-resistant species. Felicitation of EDCs/community for creation of new forests and forest protection efforts. Also, the community should be provided with horticultural plants along with mangrove associates for plantation in their lands and buffer zones – Forest, Environment and Climate Change Department	**Very High[26]**	**Very High**	**Very High**

[24]Plantation in denuded area is continuing by forest department as a part of management plan.

[25]Plantation will be sustainable with a decreased rainfall.

[26]Forest department is focusing on re-plantation of mangroves in the management plan.

THREATS (high and very high)	IMPACTS (direct impacts)	ADAPTATION OPTIONS	PRIORITY ADAPTATION		
			Feasibility	Effectiveness	Priority
EXTREME EVENTS					
Sea level rise - **Very High**	• Reduction in Ramsar Site area • Mangroves along the northern coastal section of the site, and along the central coastal strip. will be lost amounting to approximately 20% of the forests[27]. • Also, fringing mangroves along creeks will be lost.	The Water Resource Department has a plan to protect Odisha's coast, which is vulnerable to tidal surges, by constructing a 380 km saline embankment (stone and iron net structure) and massive plantation of mangrove associates along the embankment. In addition, the Forest, Environment and Climate Change Department and the Revenue Department jointly identify open lands along the banks of the rivers and areas as buffer zones for plantation.	Very High[28]	Very High[29]	Very High
		Training of the community in nursery raising, plantation and maintenance. The focus should be given to the involvement of women. Communities should also be made responsible and accountable to plantation. Activity of the Forest, Environment and Climate Change Department	High[30]	High	High
	The mangrove forest species composition will change with the loss of saline-intolerant species.	Maintenance of density of the frontline mangrove forest along the coastline to minimise the damage from the wind velocity during cyclones – Forest Department	High[31]	High	High
Cyclone - **Very High**	Already cyclones have seriously damaged the mangroves – and systems under stress tend not to recover. The anticipated increase in cyclone occurrence and severity will lead to forest losses.	Recharge aquifer with rainwater in the mangrove forest area – measures such as earthen bunds, percolation ponds, sub-surface dykes and other appropriate technologies are to be implemented by the Forest, Environment and Climate Change Department.	Very High[32]	Very High	Very High
		Maintenance of density of high cyclone resistant species *Phoenix paludosa* and *Avicennia*. Protection and increasing of density of Nalia grass – Forest, Environment and Climate Change Department	Very High	Very High	Very High
		Trimming of *Phoenix paludosa* for maintaining density – Forest, Environment and Climate Change Department	High	High	High

[27]The natural adaptation response of mangroves to sea level rise is to move inland – but in this case there is little area for potential mangrove colonisation. On the other hand mangroves accumulate sediments from the river and ocean currents and can raise the land level.

[28]Water resource department has planned for 380 km Saline embankment along with massive plantation of estimated cost 1944 crore (informed by Odisha state Water Resources department, 2021) (-)

[29]Based on the sustainability of 52 km embankment constructed earlier.

[30]Forest department can involve community in plantation program to increase community participation in protection.

[31]Management plan of forest department has a scope for including research study on Mangroves in relation to climate change.

[32]The Forest Department has further plans for maintaining the density of the frontline mangrove forest along the coastline.

THREATS (high and very high)	IMPACTS (direct impacts)	ADAPTATION OPTIONS	PRIORITY ADAPTATION		
			Feasibility	Effectiveness	Priority
EXTREME EVENTS					
Storm surge - **High**	Fringing mangroves along creeks will be lost.	Maintenance of density of frontline mangrove forest cover along the coastline to minimise the damage from wind velocity during cyclones – Forest, Environment and Climate Change Department	High	High	High
	Mangrove seeds will be washed away, which will minimise self-propagation.	Maintenance of density of frontline mangrove forest cover along the coastline to minimise the damage from wind velocity during cyclones – Forest, Environment and Climate Change Department	Very High	Very High	Very High

ANNEXURE 5: Vulnerability Assessment Field Report Template

CC THREATS	**DESCRIPTION OF THREATS** *Circle relevant threat in list provided and describe how it relates to the target system and its components.*
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	
Drought	
Sea Level Rise	
Cyclones	

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

ANNEXURE 6: 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 India MoEFCC capacities are in place, results from multiple GCMs and multiple downscaling techniques can be made available to infrastructure sectors on a regular and on-demand basis through the DHM portal and as a result 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 flood plains 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:

1. 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. Local residents and government officials have a vivid memory of depth, duration and extent of the floodwaters or areas affected by drought, for example, 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.

2. 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 13):

(i) 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.

ii) 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.

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.

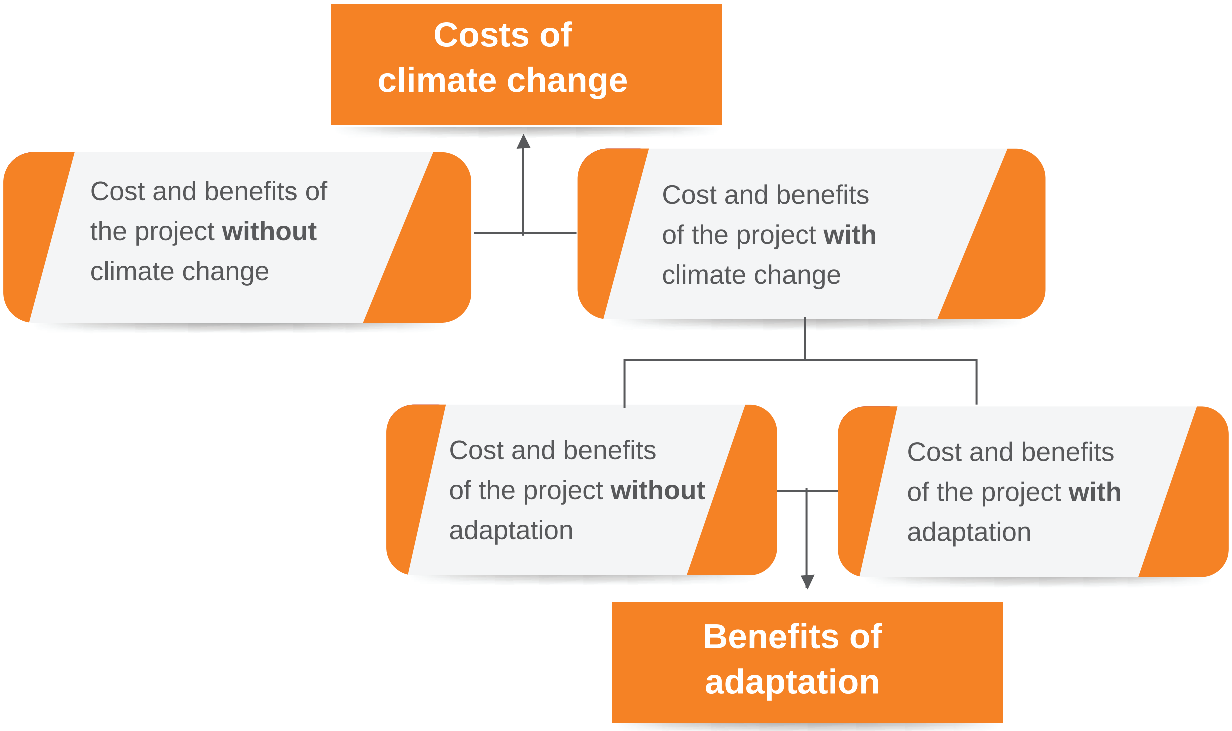


Figure 13 *Economic Assessment of Climate Change Impact and Adaptation*

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 14). 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.

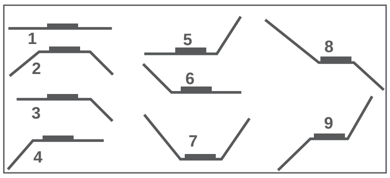
Monitoring and evaluation tools: M&E is critical to continuous learning and adjustment to adaptation measures based on performance and changing conditions. An M&E framework needs to be defined as part of the adaptation plan. The framework needs to identify responsibilities, frequency and indicators for 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[33].

10. Structure

0 None
1 Pipe culvert
2 Box culvert
3 Bridge
4 Retaining wall

10. Cross-section



12. Ditch

0 Not required
1 Effective
2 Partially blocked
3 Blocked
4 Missing

14. Access Condition

0 No issues
1 <10% access affected
2 10-25% access affected
3 25-50% access affected
4 >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 soil

17. Earthwork Angle

0 0
1 1-10
2 10-20
3 20-45
4 45-75
4 >75

18. Earthwork Height

0 0
1 0-3 m
2 3-6 m
3 6-12 m
4 12-25 m
4 >25 m

19. Earthwork Material

1 Slity clay
2 Silt
3 Clay

20. Earthwork Condition

0 No issues
1 Minor surface erosion
2 Minor slopeface failure
3 Severe gulleying
4 Moderate slopeface failure
5 Major slopeface failure

21. Vegetation

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

22. Natural Slope Length

1 <5 m
2 5-20 m
3 20-100 m
4 100-500 m
5 >500 m

23. Natural Slope Angle

0 0
1 1-10
2 10-20
3 20-45
4 45-75
5 >75

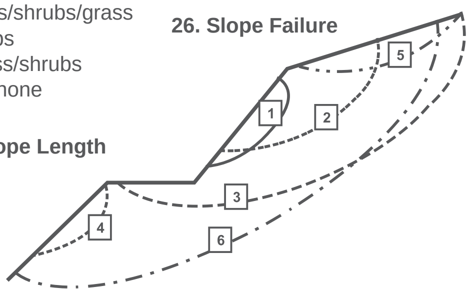
24. Natural Vegetation

0 0
1 Mature trees/shrubs/grass
2 Dry cultivation
3 Sparse grass
4 Irrigated cultivation

25. Natural Slope Condition

0 No issues
1 Minor erosion
2 Minor surface failures
3 Significant upslope instability
4 Significant downslope instability
5 Instability across allignment

26. Slope Failure



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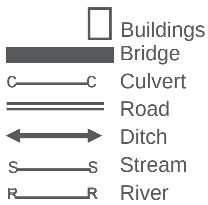

Figure 14 *Geotechnical survey data code for field assessment sheet developed by ICEM*

33 GoN, 2001.

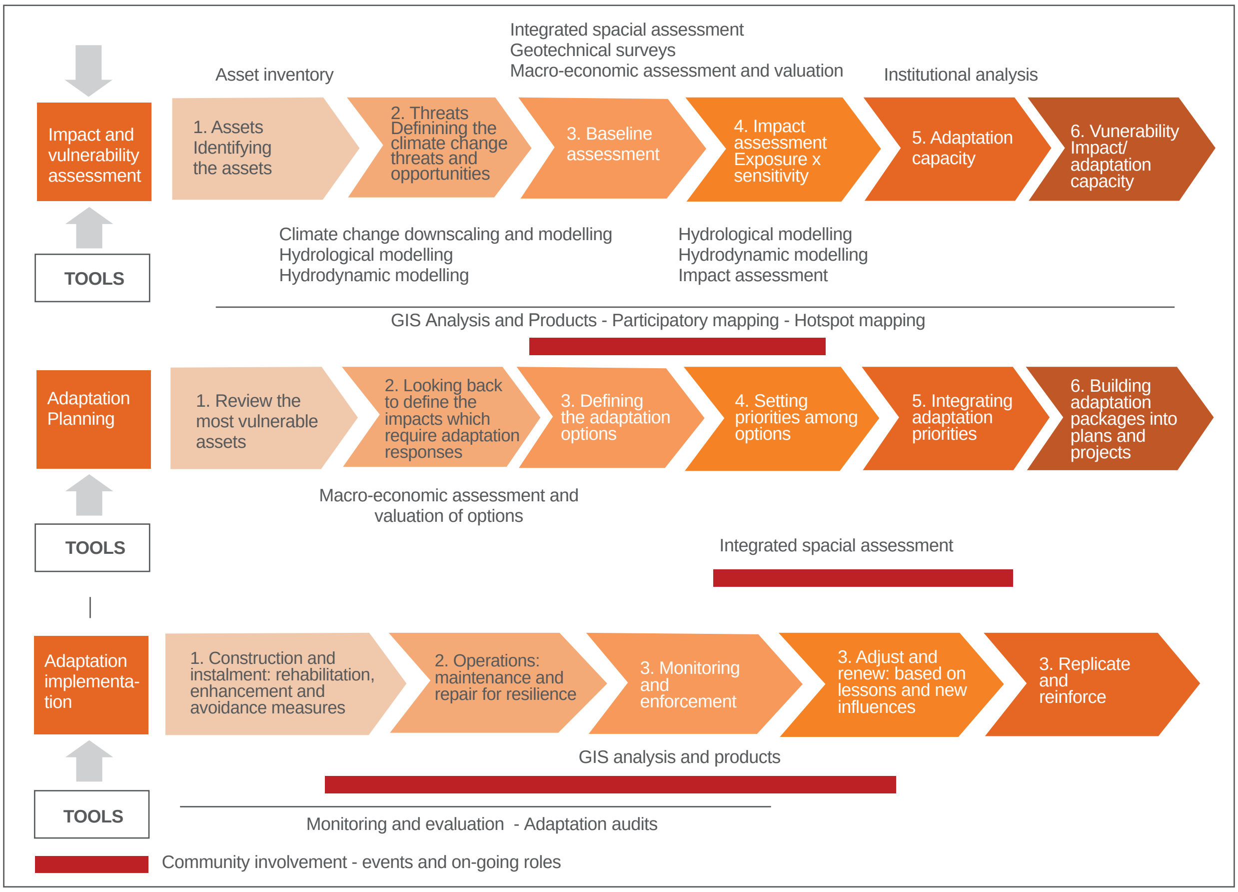

Figure 15 *Application of tools in the vulnerability assessment and adaptation process*

ANNEXURE 7: 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 the infrastructure and other assets to withstand the increasing intensity and frequency of climate events. Adaptation might include more regular and effective maintenance and protection measures and redesigning 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 the desired resilience.

Adaptation audit - Documenting adaptive measures taken by the 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 programmes.

Adaptation impact assessment - Adaptation measures can have unwanted impacts on other geographic areas and on other sectors that 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 that need to be taken to address the known impacts from past climate variability and extreme events, irrespective of climate change, but which will 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 using 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 damage, 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, the construction and maintenance of which are the responsibilities of a sector department, as well as 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’. More rigorously, it is 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 parametrisations 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 projections.

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, inter-annual 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 will occur for a doubling of CO_2 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 that is considered unalterable or recoverable only on very long-time scales, such as widespread bleaching of *corals* or collapses 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 variations in natural or *anthropogenic* external forcing (external variability). See also *climate change.*

Downscaling - A method that derives local- to regional-scale (10–100 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 - 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 - 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 a 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 a 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 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 will 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 of 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; and (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 these events having 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 the point 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 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 when it happens. 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 affected 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., damage caused by more frequent flooding due to increased water flows and volumes 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, for example, a river channel, expressed in m^3/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 or magnitude of a system process at which a 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 a 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.

Wetlands Management for Biodiversity and Climate Protection

This project is part of the International Climate Initiative (IKI). The German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) supports this initiative on the basis of a decision adopted by the German Bundestag.

On behalf of the BMUV and as part of IKI, the project 'Wetlands Management for Biodiversity and Climate Protection' is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in close collaboration with the Ministry of Environment, Forest and Climate Change (MoEFCC) and State Wetland Authorities of Himachal Pradesh, Odisha and Tamil Nadu.

Objective

The main objective of the project is to strengthen the institutional framework and capacities for an ecosystem-based integrated management of Wetlands of International Importance (Ramsar Sites) in India.

Approach

The Wetlands Management for Biodiversity and Climate Protection project is implemented in close cooperation with the National Plan for Conservation of Aquatic Ecosystems of the Ministry of Environment, Forest and Climate Change. Four main output areas define the implementation approach of the project:

I. Integrated management planning for 3-4 pilot Ramsar Sites based on biodiversity, ecosystem services and climate change risks.
II. Capacity development of national, state and site level stakeholders for integrated wetland management.
III. Development of a wetland monitoring system, including an instrument to track management effectiveness.
IV. Implementation of ecosystem-based sustainable livelihood measures as a Green Recovery measure post-COVID-19

Four Ramsar Sites have been selected as pilot sites under the project: Pong Dam and Renuka Lake in Himachal Pradesh, Bhitarkanika Mangroves in Odisha, and the Point Calimere Wildlife and Bird Sanctuary in Tamil Nadu.

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