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Addressing Climate Change within Disaster Risk Management

A Practical Guide for IDB Project Preparation

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Environmental
Safeguards Unit

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ACRONYMS AND ABBREVIATIONS

ASICDOM	Asociación de Ingeniería y Consultoría Dominicana
AOGCM	Atmosphere-ocean General Circulation Model
CAPRA	Central America Probabilistic Risk Assessment
CARDIN	Caribbean Disaster Information Network
CCKP	Climate Change Knowledge Portal
CCORAL	Caribbean Climate Online Risk and Adaptation TooL
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CCS	Climate Change & Sustainability Division
CDMP	Caribbean Disaster Mitigation Project
CEDRIG	Climate, Environment, and Disaster Risk Reduction Integration Guidance
CIMH	Caribbean Institute for Meteorology and Hydrology
CMIP	Coupled Model Intercomparison Project
CMIP3	Coupled Model Intercomparison Project Phase 3
CMIP5	Coupled Model Intercomparison Project Phase 5
DPC	Direction de la Protection Civile
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
ESG	Environmental Safeguards Unit
GCM	Global Climate Model
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GLOSS	Global Sea Level Observing System
HAZUS	Hazards U.S.
IDB	Inter-American Development Bank
IFC	International Finance Corporation
INE/RND	Division of Environment, Rural Development and Disaster Risk Management
IPCC	Intergovernmental Panel on Climate Change
LiDAR	Light Detection and Ranging
MET	Meteorological
M&E	Monitoring and Evaluation
NAPA	National Adaptation Programmes of Action
NARCCAP	North American Regional Climate Change Assessment Program
NOAA	U.S. National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Cooperation and Development
PRECIS	Providing Regional Climates for Impacts Studies
PSMSL	Permanent Service for Mean Sea Level
RCM	Regional Climate Model
SLOSH	Sea, Lake, and Overland Surge Hurricane
SRTM	Shuttle Radar Topography Mission

Acronyms and Abbreviations

SST	Sea Surface Temperature
UNEP	United Nations Environment Programme
UNESCO/IOC	United Nations Educational, Scientific and Cultural Organization/Intergovernmental Oceanographic Commission
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction
USAID	U.S. Agency for International Development
WCRP	World Climate Research Programme

KEY CONCEPTS

This Technical Note draws upon key concepts from both the climate change and disaster risk reduction communities of practice. As each community has developed distinct definitions related to risk assessment and risk management, it is prudent to define key concepts and specify the terminology that will be used here.

- **Adaptive capacity**: The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (NRC, 2010).
- **Climate variability:** 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 (IPCC, 2007).
- **Climate change:** The United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, 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'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. See also Climate change commitment, Detection and Attribution.
- **Climate change risk management** is used here as interchangeable with the definition of **adaptation**, which is: "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects" (IPCC, 2014).
- **Disaster**: the occurrence of an extreme hazard event that impacts vulnerable communities causing substantial damage, disruption and possible casualties, and leaving the affected communities unable to function normally without outside assistance (Benson and Twigg, 2007).
- **Disaster preparedness:** Activities and measures taken in advance to ensure an effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations (IDB, 2008). Contingency planning is part of disaster preparedness.
- **Disaster risk management:** The systematic process that integrates risk identification, prevention, mitigation and transfer, as well as disaster preparedness, emergency response and rehabilitation/reconstruction to lessen the impacts of hazards (IDB, 2008).
- **Disaster risk reduction**: The systematic development and application of policies, strategies and practices to minimize vulnerabilities, hazards and the unfolding of disaster impacts throughout a society, in the broad context of sustainable development (UN, 2004 in IDB, 2008).
- **Exposure**: The presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected by climate change effects (IPCC, 2012).
- **Financial protection:** *Ex ante* activities to prepare financial mechanisms or instruments for risk retention and transfer in order to have *ex post* access to timely economic resources, which improves the response capacity in the event of disasters.

Key Concepts

- **Hazard** is the "potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources." (IPCC, 2014). This definition recognizes that hazards exist under current conditions, and may be exacerbated under future climatic conditions.
- **Mitigation** is defined here as "a human intervention to reduce the sources or enhance the sinks of greenhouse gases" (IPCC, 2014). It should be noted that the term mitigation is often used in the disaster risk reduction lexicon as reducing (e.g., mitigating) the impacts of hazards.
- **Resiliency** is defined as "the capability of a system (such as a community) to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimal damage to social well-being, the economy, and the environment" (NRC, 2010). This concept recognizes that climate change adaptation and disaster risk reduction are complementary.
- **Rehabilitation:** Provisional repairs of damaged infrastructure, social services or productive capacity to facilitate the normalization of economic activities (IDB, 2008).
- **Reconstruction:** Construction of new facilities to replace those that were destroyed or damaged beyond repair by a disaster, to standards that avoid the rebuilding or increasing of vulnerability (IDB, 2008).
- **Risk**: A combination of the magnitude of the potential consequence(s) of hazard and the likelihood that the consequence(s) will occur (NRC, 2010). In the context of this report the hazards of interest are those that are exacerbated by climate change.
- **Risk reduction:** The systematic development and application of policies, strategies and practices to minimize vulnerabilities, hazards and the unfolding of disaster impacts throughout a society, in the broad context of sustainable development. Includes mitigation and prevention. *Mitigation (reduce the existing risk):* Structural and non-structural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards. *Prevention (prevent new conditions of risk):* Activities to avoid the adverse impact of hazards and means to minimize the impacts of related disasters.
- **Risk transfer:** The process of formally or informally shifting the financial consequences of particular risks from one party to another. Insurance is a well-known form of risk transfer, where coverage of a risk is obtained from an insurer in exchange for ongoing premiums paid to the insurer.
- **Sensitivity**: The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise).
- **Slow onset versus rapid onset hazard**: Slow onset hazards are those that occur over months or years (such as sea level rise or drought), and rapid onset hazards occur over shorter time intervals, such as hurricanes, floods, or storm surges.
- **Vulnerability**: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (NRC, 2010).
- **Weather**: The atmospheric conditions at a particular place in terms of air temperature, pressure, humidity, wind speed, and rainfall. Weather is what is happening now or is likely to happen in the very near future.

1.0 Introduction

Extreme weather events and climate variability, whether occurring under present or future climate conditions, can have severe consequences for development and pose risks to human health and safety and the environment. Across the Latin American and Caribbean (LAC) region and globally, climate change is causing increasing air temperatures and rising sea levels. Climate change is expected to exacerbate flooding, hurricanes, prolonged drought periods, shifts in precipitation patterns, and extreme heat conditions. Social, ecological, and economic vulnerabilities to such weather events currently exist across LAC. Climate change will exacerbate existing vulnerabilities and could also create new risks.[1]

Additionally, there is a growing recognition that implementing climate change risk management strategies contributes to the overall resilience of a project, and therefore its long-term sustainability. Businesses and communities can face many stressors, such as rapid population increases, aging public infrastructure, economic fluctuations, and natural hazards. Resilience is the ability to continue to thrive in the face of those stressors. The environmental impact of climate change is anticipated to exacerbate current stressors and to make the future environment more unpredictable. Indeed, resilience has become a central concept of Inter-American Development Bank (IDB) operations; for example, as a component of IDB's *Sustainable Infrastructure for Competitiveness and Inclusive Growth* (IDB, 2013).

In recognition of the hazards posed by climate change to the LAC region and its lending operations, and the opportunities to develop more resilient and sustainable projects, the IDB recently placed institutional emphasis on climate change risk management. As part of the IDB's Ninth General Capital Increase (GCI-9, 2010) climate change was identified as a priority area for Bank activities. Thus the Bank was required to develop an Integrated Strategy for Climate Change Adaptation and Mitigation, and Sustainable and Renewable Energy (2011). Climate change risk is acknowledged within Directive A.6 of the Environmental and Social Safeguard Compliance Policy (OP-703, 2006) and its Implementation Guideline (2007b), as well as in Policy Guidelines 1.7 and 1.8 of the Disaster Risk Management Safeguard and Policy (2007a) and its Implementation Guideline (2008).

The IDB has a crucial role to play in promoting climate change risk management by assisting borrowers to identify and implement resiliency strategies. A recent review of IDB's climate change support by the Office of Evaluation and Oversight (2014) found that identifying and addressing climate change risk and reducing vulnerability are challenges for most sectors and project teams in IDB. As a result, the Environmental Safeguards unit (ESG) has, in consultation with the Division of Environment, Rural Development and Disaster Risk Management (INE/RND) and the Climate Change and Sustainability Division (INE/CCS), developed a combined disaster risk and climate change risk management screening process to identify project risks at an early stage of the project cycle.

This Technical Note is another step in managing climate change risks in the project cycle. We are aware that it is very difficult— if not impossible in the short term —to differentiate between risks caused by climate variability and climate change. Thus, this document addresses both types of risks under the term "climate change risk" and emphasizes that risk assessment has to take into account the possible additional risks caused by climate change. It is aimed at providing guidance to project proponents (clients, sponsors, borrowers, and executing agencies) on options for addressing the climate risks identified in IDB financed investments. This document is a follow up to the Technical Note: *Climate*

[1] For example, climate change could create water stress in areas that have not experienced such stress or create new vector-borne disease risk (such as malaria, dengue fever) in areas that have not experienced those diseases due to increased air temperatures.

Change Data and Risk Assessment Methodologies for the Caribbean (Tetra Tech, 2014).[2] In that document, the IDB introduced a climate change risk assessment framework, which included a process for climate change risk assessment and risk management. Although *Climate Change Data and Risk Assessment Methodologies for the Caribbean* provided detailed information on the initial risk screening and assessment steps, the response and the possible risk management options were not discussed in detail. This Technical Note provides a summary of those initial steps to provide the background, but focuses more on the identification, implementation, and monitoring of the climate change risk management options.

The purpose of this Technical Note is to identify climate change risk management options that can be incorporated into IDB investments and to present considerations for monitoring and evaluation strategies to track the effectiveness of such actions. While there has been significant progress worldwide in conducting climate change vulnerability and risk assessments, climate change risk management is still in early stages of implementation and study. Thus, there is neither a significant amount of lessons learned nor robust evaluations of the effectiveness of risk management activities and investments. This note seeks to identify early lessons in climate change risk management, including risk management options that have proven effective in strengthening resilience based on literature from the disaster risk reduction (DRR) community. It is hoped that the climate change risk management options and strategies presented herein will provide a foundation for the IDB to build upon, as additional information becomes available and options are further tailored to meet the needs of specific sectors, regions, and IDB priorities.

[2] Technical Note No.IDB-TN-633, *Climate Change Data and Risk Assessment Methodologies for the Caribbean*, is available here: <http://publications.iadb.org/handle/11319/6453?scope=123456789/1&thumbnail=false&order=desc&rpp=5&sort_by=score&page=0&query=climate+change+data+risk+assessment&group_by=none&etal=0> and the accompanying factsheet available here: <http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=38769737>.

2.0 Climate Change Risk Assessment Methodology

This section provides an overview of the climate change risk assessment and management framework identified in *Climate Change Data and Risk Assessment Methodologies for the Caribbean* (Tetra Tech, 2014). Figure 1 illustrates the framework and associated steps. The following climate change risk assessment methodology steps were developed for use by Bank project proponents:

- Step 1: Screen for climate and climate change risk. Review the project to determine whether further climate change related analysis is necessary.[3]
- Step 2: Define the assessment parameters. This includes defining the site and planning horizons and identifying and gathering relevant data to better understand what type of vulnerability assessment will be conducted.
- Step 3: Assess climate and climate change risk and identify risk management strategies. Conduct a basic vulnerability or detailed risk assessment to identify how susceptible the project is to climate and climate change hazards (such as sea level rise, hurricanes, flooding, and drought). Identify strategies to address identified risks, vulnerabilities, or impacts.
- Step 4: Implement, monitor, report. Implement climate and climate change risk management strategies. Evaluate the effectiveness and efficiency of the measures implemented (on the ground *ex post* evaluation[4] and comparison with the *ex ante* evaluation[5] done in step 3)

The approach is structured as a tiered process with the flexibility to stop after project screening (Step 1) or determine if a basic vulnerability assessment or more complex risk assessment is necessary for the proposed project (Step 3).

As IDB has integrated climate change risk assessment in the disaster risk management procedures for projects proposed for IDB financing, the present framework has been developed so that the findings of the risk assessment can be directly incorporated into documents required by the Bank as part of its project appraisal.

While the climate change risk management guidance included in this document can be considered generally applicable to addressing climate change risk; the guidance has been developed specifically to inform Step 3 (assess risk and decide on climate change risk management options) and Step 4 (implement, monitor, and report) of the framework. The primary purpose of this Technical Note is to help identify climate change risk management measures to minimize the risk posed by climate change to IDB investments.

[3] Please note that this screening is different from the IDB project Environmental and Social Safeguard Screening completed by IDB project teams during the early appraisal of projects proposed for IDB financing.

[4] The *ex post* evaluation of operations at the Bank aims to assess the extent to which the development objectives of IDB-financed operations have been attained. The *ex post* evaluation of operations also aims to assess the efficiency with which those objectives have been attained. It is called an *ex post* evaluation since the purpose is to evaluate the results of an operation, particularly in terms of its outcomes and/or impact, after it has been completed. For more refer here: <http://www.iadb.org/en/about-us/evaluation-of-idb-operational-objectives,6242.html>

[5] The *ex ante* evaluation is conducted pre-intervention and describes the situation prior to an intervention, against which progress can be assessed or comparisons made. Baseline data are collected before a program or policy is implemented to assess the "before" state.

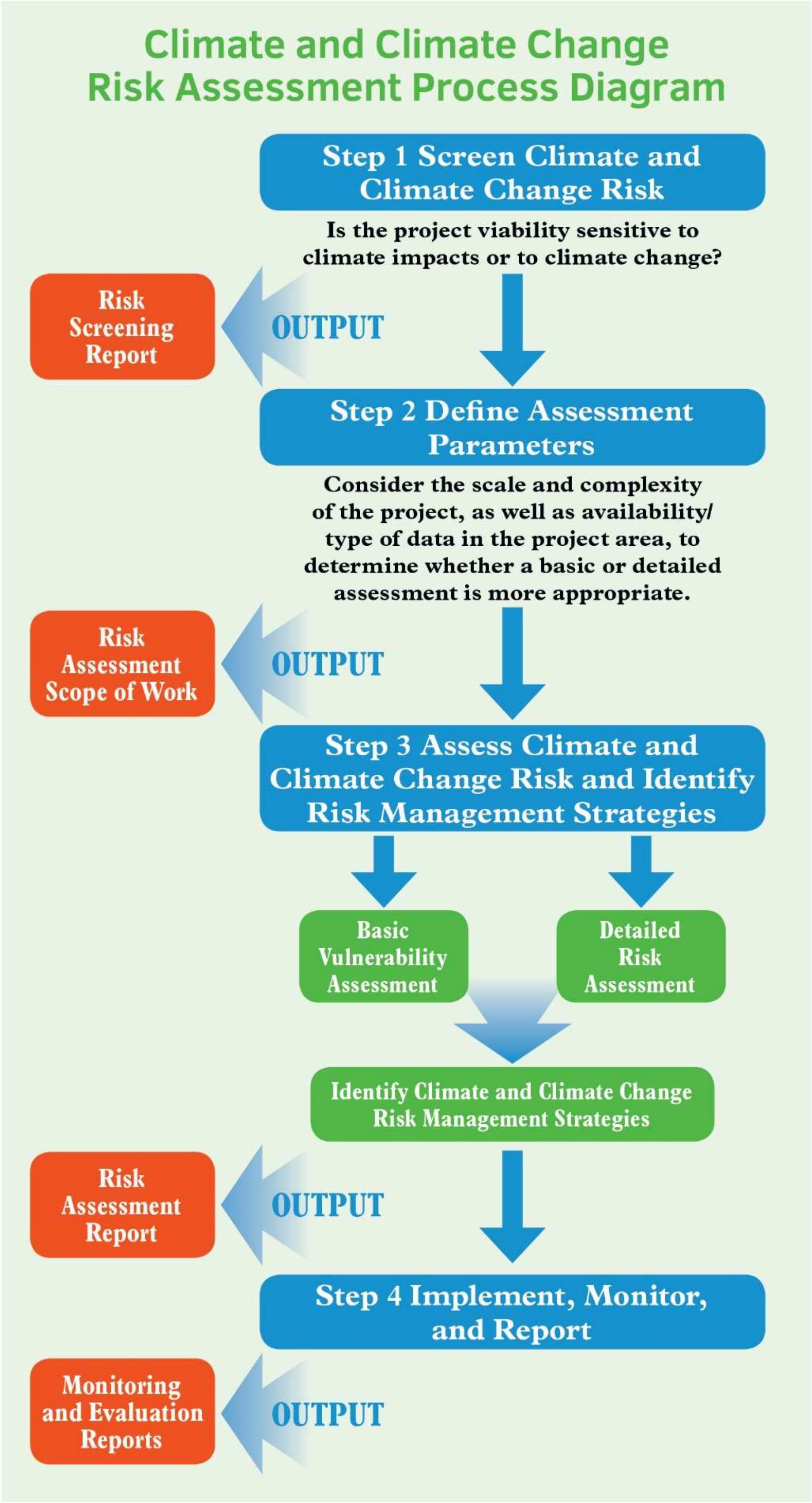

Figure 1. Climate and climate change risk assessment framework diagram.

3.0 Climate Change Hazards To Be Addressed

Climate change can create and exacerbate hazards which need to be understood in order to manage and adapt to them. The hazards listed below are not meant to be an all-inclusive list but those most likely to have greater impact on IDB projects. The sections below define each of these hazards and how they are altered by climate change, and provide a basic understanding of potential impacts to IDB projects.

3.1 Sea Level Rise

Sea level rise, a slow onset hazard occurring over decades, can exacerbate other hazards such as storm surge and coastal flooding. Higher atmospheric temperatures are linked to melting glaciers and continental ice masses, and an expansion of sea water molecules which creates higher global sea levels. Local sea levels provide a water height with respect to the local ground surface. These local sea levels factor in land subsidence, glacial rebound, and other ground motion. Some areas experience much higher sea level increases when compared to the global average while others show a much lower level due to the coastline rising.

The global rate of sea level rise in the 20th century was 1.7 ± 0.5 millimeters (mm) per year (IPCC, 2007). Over a more recent period, 1993–2003, the global increase has been reported to be 3.1± 0.7 mm per year using satellite altimetry data (National Academy of Sciences, 2012).

Projects located on the shoreline or projects which depend on infrastructure or resources located on the shoreline are particularly vulnerable. As such, sea level rise is of particular importance to the LAC region because of numerous small island nations and extensive exposed coastlines throughout the region; however, specific data for the region are sparse and there is still insufficient data to identify a trend in sea level within the LAC region. It is important to note that sea level is locally driven by site specific factors such as erosion, geological composition, and land movement. Rising seas have the potential to impact many of the sectors supported by the IDB.

3.2 Hurricane Wind and Storm Surge

Hurricanes are a rapid onset hazard which includes high wind and surge components. A hurricane is an intense tropical weather system with a well-defined circulation and minimum sustained winds of 74 mph (64 knots) or higher (NOAA, 2014). Climate change is predicted to warm the oceans and increase the magnitude of hurricane events while sea level rise exacerbates the storm surge.

Hurricanes are a climatic extreme with significant consequences over much of the Caribbean and parts of Latin America. Most of the hurricanes occur between 10°N and 20°N latitudes in an area known as hurricane alley in the Atlantic. Available data on hurricane frequency and intensity shows no clear pattern over a 160-year period of historical record, during which there have been observable increases in global mean temperature.

Tropical cyclones and hurricanes generally form in areas with high sea surface temperatures (SST), and the intensity of these events is also related to SST.

Based on current focused research on hurricanes, the following conclusions are relevant from a climate change risk assessment perspective for the LAC Region:

- Anthropogenic warming by the end of the 21st century will likely cause hurricanes in Central America and the Caribbean region to be more intense on average (by 2 to 11% for mid-range emission scenarios). This change would imply an even larger percentage increase in the destructive potential per storm, assuming no reduction in storm size.
- On average across the globe, assuming global climate changes within the range deemed most likely, the frequency of tropical cyclone and hurricane occurrence is expected to decrease by 6 to 34% (Knutson et al. 2010).
- Climate warming over the next century may lead to an increase in the numbers of very intense hurricanes in some basins—an increase that would be substantially larger in percentage terms than the 2 to11% increase in the average storm intensity. This increase in intense storm numbers is projected despite a likely decrease (or little change) in the global numbers of all tropical storms.
- Anthropogenic warming by the end of the 21st century will likely cause hurricanes to have substantially higher rainfall rates than present-day hurricanes, with a projected increase of about 20% for rainfall rates.

From a practical standpoint, therefore, climate change risk assessments in this region may justifiably consider the impacts of more intense storms and hurricanes in a given location compared to storms documented in the historical record.

Hurricanes have the potential to impact all sectors supported by the IDB. Projects located on the shoreline or projects which depend on infrastructure located on the shoreline are particularly vulnerable. Relatively flat areas with little to no vegetation and buildings may also experience very high winds much further inland than the surge zone. A structure's vulnerability is related to the ability to keep its envelope intact and remain out of the surge zone.

3.3 Flooding

A flood may be a rapid onset hazard or a slow onset hazard in the case of coastal tidal flooding. It is the temporary condition of partial or complete inundation of normally dry land (modified from FEMA, 2014). Statistically downscaled temperature and precipitation values, both historical and projected, are available from the CMIP3 projections from the World Bank's Climate Change Knowledge Portal in a form that is easily accessible. In much of the LAC region, the projections show a pattern that is typical among GCMs: greater agreement on temperature projections than on precipitation projections. CMIP5 projections are also available from WorldClim. At this site, a set of global climate layers (climate grids) with a spatial resolution of about 1 square kilometer is provided.

In a riverine flood hazard assessment, there are two processes which need to be understood: (1) the hydrology of the watershed and (2) the channel hydraulics. Hydrologic models represent the distribution of rainfall, with the ultimate goal of obtaining a discharge and flood hydrograph for the streams and rivers. Hydraulic models take the output from the hydrologic models, along with the stream channel morphology, to generate flood elevations. These flood elevations are used to create flood elevation and flood depth grids.

In a coastal flood hazard assessment, there are three components which need to be understood: (1) the coastal erosion process, (2) the wave height analysis, and (3) the wave run-up analysis. Sea-level rise is producing higher rates of erosion and this process needs to be understood and quantified at the beginning of a coastal flood or hurricane surge assessment. The wave height and run-up analysis will result in a coastal flood elevation.

Floods have the potential to impact all sectors supported by the IDB. Projects located adjacent to rivers, lakes, shorelines, and other bodies of water may be subjected to flooding. Sea level rise may also exacerbate coastal flooding. Projects which depend on infrastructure located in these susceptible areas are particularly vulnerable. A structure's vulnerability is related to its elevation (or critical component elevations) with respect to the flood waters. Projects located in and adjacent to floodplains with substructures are particularly vulnerable to flooding.

3.4 Drought

A drought is a slow onset hazard brought on by a lack of precipitation, higher temperatures and winds, low relative humidity, greater sunshine, and less cloud cover. High water demand and insufficient management may also exacerbate a drought condition. Statistically downscaled temperature and precipitation values, both historical and projected, are available from the CMIP3 projections from the World Bank's Climate Change Knowledge Portal in a form that is easily accessible. In the LAC region, the projections show an increase in temperatures. CMIP5 projections are also available from WorldClim. At this site, a set of global climate layers (climate grids) with a spatial resolution of about 1 square kilometer is provided.

Droughts have the potential to impact all sectors supported by the IDB. Although projects may not be directly damaged by a drought, there may be many indirect impacts. If a project requires water, especially large quantities of water, it can be impacted by a drought. Droughts impact drinking water supply and availability, which could cause shortages or water restrictions for affected communities. Tourists and other visitors may stay away from a drought stricken location and agriculture may be lost.

3.5 Extreme Temperatures

Extreme temperatures are a rapid onset hazard defined by temperatures that are 10 degrees or more above the average high temperature for the region and last for prolonged periods of time or an unhealthy temperature for any length of time (New York, Office of Emergency Management, 2014). Extreme temperatures may be exacerbated by electric grid failures. Statistically downscaled temperature and precipitation values, both historical and projected, are available from the CMIP3 projections from the World Bank's Climate Change Knowledge Portal in a form that is easily accessible. In the LAC region, the projections show an increase in temperatures. CMIP5 projections are also available from WorldClim. At this site, a set of global climate layers (climate grids) with a spatial resolution of about 1 square kilometer is provided.

Extreme temperatures have the potential to impact all sectors supported by the IDB. Projects relying on heat-susceptible machinery or producing heat-susceptible products or agriculture are especially vulnerable. Although projects may not be directly damaged by extreme temperatures, there may be many indirect impacts. Transportation and utilities may be impacted by extreme temperatures while tourists and other visitors may stay away from a very hot location.

3.6 Ecosystem changes

Slow onset climatic processes, including rising air and water temperature, changes in precipitation, and ocean acidification, are affecting the composition and functions of terrestrial and aquatic ecosystems. Many of the species that depend on these ecosystems will also be impacted. Climate change is projected to shift the geographic ranges, change the timing of seasonal and migratory behaviors, and impact the abundances of many terrestrial, freshwater, and marine species. These impacts could adversely affect biodiversity, potentially resulting in extinction for particularly vulnerable species and loss of ecosystem services.

Planting and harvesting seasons could change, and agricultural yields could be adversely impacted. The food security of local populations could be severely impacted by declining crop yields and fish stocks. Ecosystem changes could also alter the distribution of some water-borne illnesses and disease vectors, which could increase health risks and disease burdens of local populations. Tourism could be impacted if tourist destinations (coral reefs, parks, etc.) are adversely impacted.

A few projects exist which track coastal ecosystems across the LAC Region including that completed by the Marine Ecosystem Services Partnership with the World Resources Institute (WRI) (www.wri.org/publication/influence-coastal-economic-valuations-caribbean). Information concerning habitats, reefs, invasive species, fish kills, and water quality may exist locally as well.

4.0 Climate Change Risk Management Options

Given current knowledge of climate change impacts (as described in Tetra Tech, 2014) and summarized in Section 3, the goal of this document is to identify the types of actions that might be taken to manage the future climate change hazards. This section provides an overview of adaptation or risk management options that might be taken in different sectors. The sectors of interest are divided into the following categories that pertain to IDB's current areas of lending support: agriculture, energy, tourism, water and sanitation, urban infrastructure, and transportation.

The nature of the adaptation measures vary. Geographically, they can range from local-scale projects to changes at regional and international scales. Institutionally, they can range from changes in zoning and insurance incentives to protecting a specific element of the infrastructure. The time horizon of actions can range from activities that can be implemented in the immediate near-term, in 1 to 5 years, or in the gradual longer term over decades. Given this broad range, this document presents potential actions at a reasonably high level, with the understanding that these concepts will stimulate more detailed responses that are scaled down to the project or region of interest.

4.1 Climate Change Risk Management in the Framework of Disaster Risk Management

The additional risks caused by climate change are structurally the same as risks caused by other natural hazards, in that they are assessed in terms of hazard, exposure, vulnerability and adaptive capacity. This is why we address climate risks within the established framework of Disaster Risk Management (DRM). DRM is the result of the integration of different processes (risk reduction, disaster management and financial protection) and sub-process (prevention, mitigation, disaster preparedness, response, recovery, risk retention and risk transfer).[6] In this context, the DRM Plan is described as follows (IDB, DRM policy):

"The DRM plan should include proposals for the design of disaster prevention and mitigation measures, including safety and contingency plans to protect human health and economic assets, and their estimated costs; an implementation plan; a monitoring program and indicators for progress; and an evaluation plan. The implementation plan includes protocols to undertake periodic safety evaluations from project implementation up to project completion and maintenance of project equipment and works."[7]

Ideally the DRM plan should be designed based on an optimal combination of the different process of DRM. In order to simplify the cost-efficiency analysis of the optimal combination of processes for DRM, countries and private institutions have adopted standards of reference that should be considered in the design of investment projects. The most common standards are the levels of acceptable risk (see text box and Figure 2 below).

[6] See Key Concepts for definitions.
[7] The IDB DRM policy is available here: <http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=35004515>.

Text box. Defining the optimal combination of DRM processes and tools.

There is an inverse relationship between the probability of an event and the magnitude of losses. The high probability or more recurring events generate less damage and losses (they are the less intense), while the low probability events generate greater damage and loss (they are the most intense). The most efficient tools to manage high probability events are risk prevention and risk reduction. This layer (layer 1) is called mitigable risk. The next layer of risk is the retainable risk, this represents the upper limit of the deductible in insurance terms and budgetary and contingency provisions are needed to deal with this layer of risk (layer 2). The next layer corresponds to low probability events (layer 3). It is called the transferable risk; that risk which could be transferred efficiently trough insurance, reinsurance or arises from capital markets (bonds). Finally there is a layer of very low probability/high impact residual risk that can only be managed though disaster preparedness.

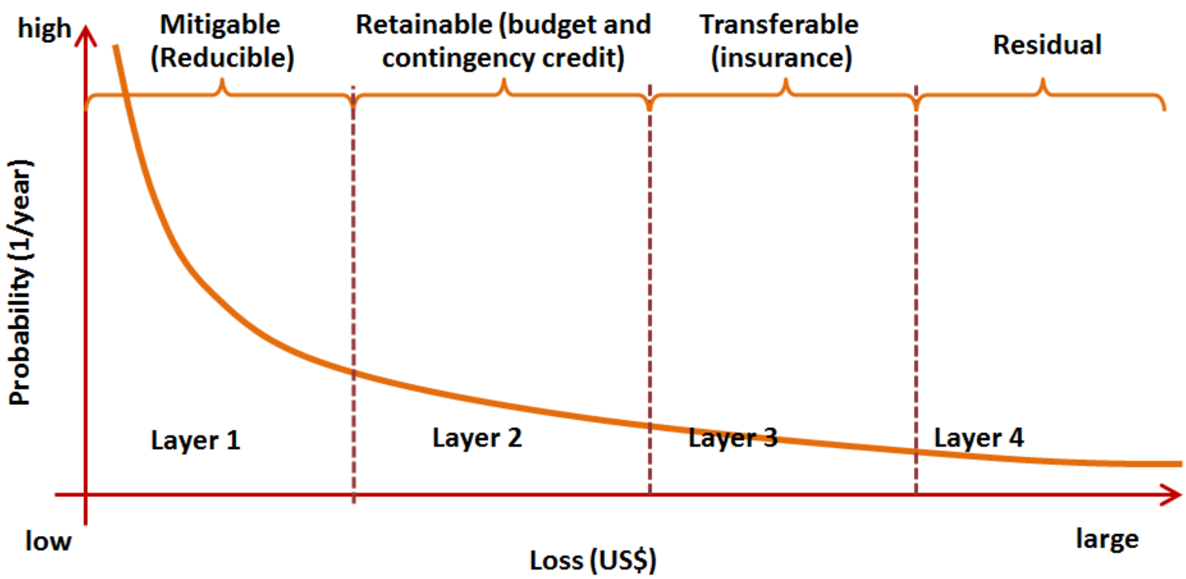

Figure 2. Idealized loss exceedance curve and risk layers.

The acceptable risk standards define limits for the mitigable risk (layer 1). Many countries and private companies have adopted standards of acceptable risk as part of building codes or land use regulations. Acceptable risks are technical references used in engineering to assess and define the structural and non-structural measures that are needed in order to reduce possible harm to people, property, services and systems to a chosen tolerated level, according to codes or "accepted practice" which are based on known probabilities of hazards and other factors (UNISDR, 2009).

The IDB DRM policy established that Bank-financed public and private sector projects will include the necessary measures to reduce disaster risk to acceptable levels as determined by the Bank on the basis of generally accepted standards and practices.

4.2 Climate Change Risk Management Options by Hazard

4.2.1 Sea Level Rise (SLR)

SLR will affect the IDB project sectors in similar ways: loss of land (via permanent flood) and potential saltwater intrusion into aquifers and surface water. There are three ways to avoid the loss of land and therefore valuable infrastructure, agriculture or property; (1) protection via hard (walls, levees, armor) and soft (wetlands, mangroves, beach nourishment) responses; (2) accommodation via building codes, building alterations or land use changes; or (3) managed retreat from the area via development restrictions and abandonment of remaining structures. Costs, feasibility of implementation, and time frame of these climate change risk management options range considerably depending upon the strategy used (Table 1 – Table 6). Every location will have differing risks and severity of impacts to the sector, so deciding to use an option and the efficacy of it will depend upon the location specifics. Infrastructure can be protected best at the planning stage where climate change risk management measures are easy to implement and will reduce long-term costs. Installing barriers and hard structures are expensive and do not fully reduce the risk of flooding. Further, hardening shorelines may exacerbate coastal erosion, impacting beaches and sand dunes. Strategies to combat saltwater intrusion exist and are used in some places but are expensive to implement.

4.2.2 Hurricane Wind and Storm Surge

Due to the rapid onset of hurricane winds and storm surges, some climate change risk management measures tend to overlap with disaster planning in regions that typically experience hurricanes. Preventive measures to avoid hurricane wind damage can be quick and relatively inexpensive to implement (Table 6). Storm surges tend to be more difficult and expensive to address, as large projects are often necessary. Emergency plans, evacuation plans and shelters can help limit the severity of the impacts and are relatively inexpensive (Table 1 to Table 6).

4.2.3 Flooding

Flooding due to hurricanes or sea level rise can be addressed with similar methods of climate change risk management. Extra pumping installations, barriers and levees, porous ground (i.e. green roof, bioretention pond, permeable pavement) and elevated structures can be implemented at moderate costs, especially at the planning stage.

4.2.4 Drought

Some strategies for managing or mitigating the impact of droughts require a decade or two and a significant financial investment for implementation. Agriculture is hit particularly hard by drought and risk management strategies are generally costly. Water conservation, diversification and restrictions are inexpensive and easily feasible.

4.2.5 Extreme Temperatures

Extreme temperatures, specifically higher temperatures, can be addressed by several climate change risk management measures. Most options are moderately difficult to implement but rapidly reduce the impacts of extreme heat. Working to enhance and/or maintain sufficient water and energy is recommended for the tourism sector (Table 3), while many low-cost and easily feasible strategies are presented for the urban infrastructure sector (shade trees, back-up generators, cooling centers; Table 5).

4.2.6 Ecosystem Changes

Changes to fragile ecosystems such as upland and coastal forests, coral reefs, wetlands, mangrove forests, and beaches/dunes tend to influence flooding rates. Management, restoration, and conservation are climate change risk management tools for addressing ecosystem changes. Some risk management strategies include fisheries management, stabilizing dunes with vegetation, and establishing marine protected areas (Table 3 and Table 5). These are relatively low cost options but require capacity to improve governance at national to local levels.

4.3 Evaluating Climate Change Risk Management Options

The goal of this document is to provide guidance that would lead a project proponent to examine and refine the risk management strategies that may apply to a specific project. Climate change risk management options are presented in Tables 1 through 6 for six sectors of interest that pertain to IDB's current areas of lending support: agriculture, energy, tourism, water and sanitation, urban infrastructure, and transportation infrastructure. Risk management options are then identified for each hazard (as identified and summarized above in Section 4.2), along with a brief description of how the option addresses the hazard.

The relative costs and implementation feasibility are indicated for each option based on the professional judgment of the authors, and only to be taken as an approximate starting point for additional analysis. The costs have been broadly categorized into four levels (identified as $ to $$$$) with the following general meaning:

- $ = Relatively straightforward to implement, either simple changes on the ground or adoption of new regulations/guidelines etc.
- $$ = Relatively small scale projects on the ground that can be implemented with modest design and planning requirements
- $$$ = Intermediate scale efforts, more spatially extensive, and or requiring more engineering design, scientific development, and or planning/institutional changes than in the above two categories
- $$$$ = Major new infrastructure development with significant new design, planning and permitting requirements

In all cases, the cost description refers to the costs associated with the specific risk management measure, not the costs that might occur should the adverse impact in question occur. The costs associated with these options will need to be estimated at the project level and will depend on the project scale and the risk level. When considering costs it is also important to evaluate not just the capital investment needed, but any recurrent costs (such as operational costs) and indirect costs screened using a number of feasibility criteria. It is also important to note that the cost estimates are representative of the cost of implementing the proposed option, as opposed to the costs of reconstruction activities following a hazardous event.

The feasibility of implementing risk management strategies will depend on evaluating various criteria against project specific considerations. This can be thought of as the probability that the option would be implemented. As described in Coppola (2015), these criteria could include:

- Political support (e.g., would political support be necessary for implementation of the proposed option? Could lack of political support decrease the possibility of implementation?)
- Public support (e.g., is the proposed option socially accepted in the community? Would implementation of the proposed option cause adverse impacts to the population or segments of the population?)

- Cost (e.g., is the proposed option cost-effective? Are there funds in place to support the option? Would implementation place a financial burden or negatively affect the income generation of the project?)
- Technical (e.g., is the proposed option technically feasible at the project site, would there be ancillary impacts?)
- Capacity (e.g., does the project proponent have the capacity to implement the proposed option, with respect to staffing, funding, maintenance requirements?)
- Regulatory/legal (e.g., what are the regulatory requirements and legal authorities needed to implement the proposed action?)
- Environmental (e.g., would the proposed option negatively affect the environment?)

The relative degree of difficulty is indicated for each option using the following four broad categories (difficult, moderately difficult, moderately easy, and easy) with the following general meaning:

- Easy = Relatively straightforward to implement, provides long-term benefits, has no adverse secondary impacts.
- Moderately easy = Minimal demands on capacity (staffing, funding, and maintenance capabilities), option is not expected to result in significant social or environmental impacts.
- Moderately difficult = Intermediate scale efforts required to implement; option could require further assessment of environmental and social impacts, additional regulatory requirements, or capacity and technical expertise.
- Difficult = Major effort would be needed to implement; option could result in adverse environment/social impacts, or could require significant expenditures, capacity, technical expertise, political will, or legal authority.

4.3.1 Additional Considerations for Assessing and Prioritizing Climate Change Risk Management Options

While cost and implementation feasibility are prerequisites for evaluating climate change risk management options, assessing and prioritizing actions will need to be based on numerous factors. Common methods of assessing and ranking climate change risk management strategies include the following (as defined in Lim et al., 2004)[8]:

- Cost benefit analysis: Involves comparing the costs and benefits of undertaking a climate change risk management option. While benefits are not always quantifiable, the costing of measures is possible as long as priced resources are used. Non-monetary factors, such as the use of scarce resources, should also be considered.
- Cost effectiveness analysis: Used when benefits cannot be measured in a reliable manner (for example, with environmental goods and services). This method principally involves the costing of different options, which achieve the same objective, and then comparing those options to determine how an objective can be reached in a least-cost way.
- Multi-criteria analysis: Consists of developing objectives, alternative measures/interventions, criteria, scores that measure the performance of an option against the criteria, and weights that are applied to the criteria. The difference between this method and the two above lies in the selection of criteria and their weights; which are judgmental elements. Multi-criteria analysis provides an opportunity to consider a variety of factors and the flexibility to determine value relevant to the project.

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[8] A useful summary of the various methods for the prioritization and selection of adaptation policies and measures is found in Annex A.8.1 in Lim et al., 2004.

- Expert judgment: This method could be employed when data availability or the complexity of the problem presents a significant obstacle to the other methods. Experts could aim to either produce suitable information for decision making and/or make a decision using judgment and existing information.

Climate change risk management options could also be evaluated within an environmental impact analysis, disaster risk assessment, or using other assessment approaches. Regardless of the method used to assess and rank options, there are several factors that should be considered within the context of the project, such as the effectiveness in reducing climate change risk, feasibility of design and maintenance, urgency of climate change risk, and other externalities such as providing benefits to the ecosystem and minimizing unintended negative consequences. Example evaluation criteria could include:

- Feasibility
  - Implementation (and maintenance, if applicable) costs compared to budget
  - Technical capacity to implement (e.g., data, technical knowledge)
  - Infrastructure to implement
  - Legal constraints
  - Acceptability to community
- Effectiveness
  - Reduces vulnerability to climate change
  - Addresses multiple vulnerabilities simultaneously
  - Improves resource condition
  - Interactions (critical interdependencies, synergies, conflicts) among actions
  - Leverage potential of work (with existing/ongoing management efforts)
  - Robust under a range of uncertainties
- Flexibility
  - Reversibility
  - Agile under changing conditions
  - Adjustable based on learning and updated climate projections
- Urgency
  - Degree of threat
  - Opportunistic timing (e.g., unexpected opportunity for funding, partnership, etc.)
  - Long lead time required to put action into place
- Externalities
  - Achieves benefits to other ecosystems as well as the target system
  - Benefits human communities as well as the target system
  - Works with external activities (of other organizations/jurisdictions) to enhance their benefits within or outside the system
  - Minimizes unintended negative consequences
  - No-regret strategies that are beneficial even if the climate change effects end up being different from present-day projections
  - Carbon footprint is minimal

A major challenge in climate change risk management is relating the level of adaptation expenditure to the uncertainty of climate change and identifying the appropriate timing of implementation. Climate change risk management options can be considered at different time scales depending on the likelihood of the risk. In some cases it is appropriate for the climate change risk management measures to be built into a project at its inception, in other instances, it may be more economical to incrementally add in risk management over time, as climate change impacts are better understood. Additionally, it is important to consider the planning and life cycle horizons of the project and climate change risk management options. For example, the annual choice of crops extends over a short time horizon and could be easily changed, while the life cycle of large scale infrastructure projects could last 50 years or more (examples of time horizons are shown in Table 3. For new infrastructure the change may be easier to implement at the design stage, although for existing infrastructure making these changes may be considerably more expensive. Therefore, a key element of this guidance is the consideration of climate change drivers and their impacts at the earliest stage of projects, where design changes are much easier to incorporate.

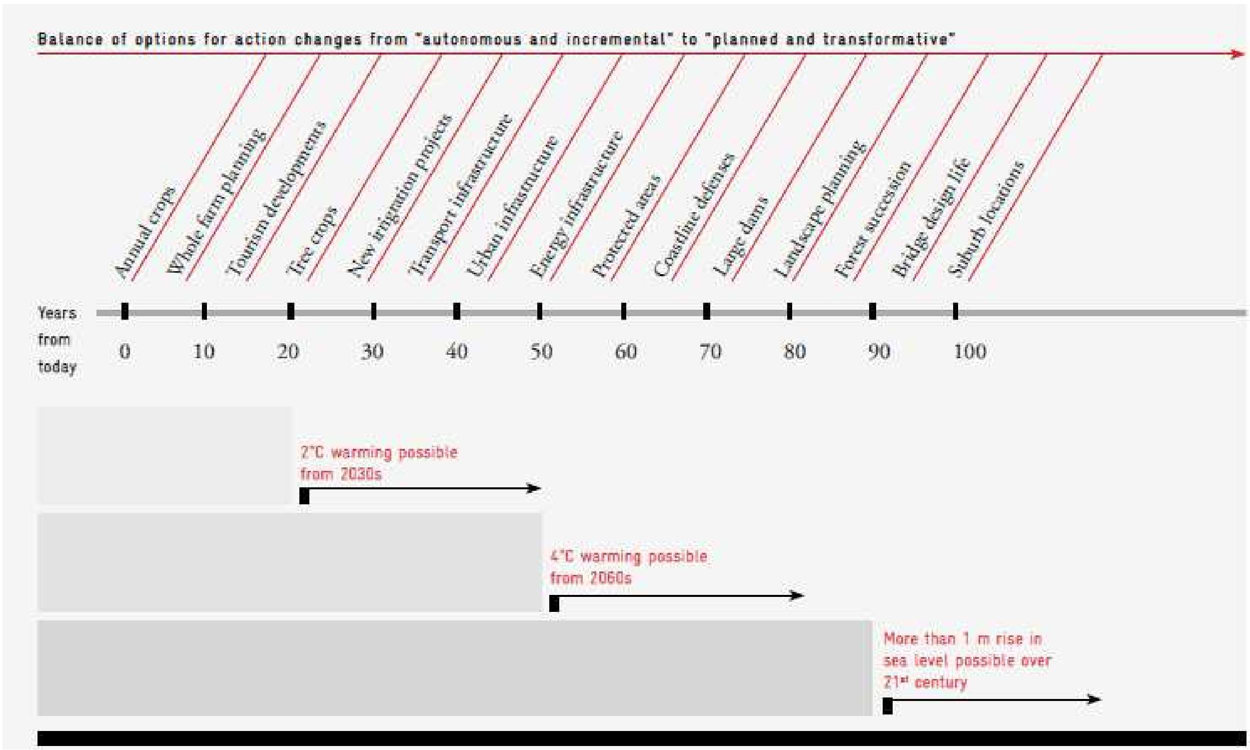

Figure 3. Planning horizons for climate change risk management (Stafford Smith et al., 2010 in GIZ, 2010).

Recognizing that the set of climate change risk management options provided is not an exhaustive list, the next step involves developing region- and location-specific strategies. This will require local input and knowledge in order to narrow down the appropriate adaptation measure(s) to take. Many climate change risk management strategies will present trade-offs that will need to be addressed based on the specific needs of the area.

It will be extremely important to monitor and evaluate the effectiveness of risk management options and strategies. Adjustments can be made in an adaptive fashion in response to monitoring data and reduced uncertainty. Any lessons learned from climate change risk management actions will provide immense value to the region.

4.4 Climate Change Risk Management Options by Sector

Climate change risk management options are presented below in Tables 1 through 6. Risk management options are identified by sector for each hazard, along with a brief description of how the option addresses the hazard, and the relative costs and implementation feasibility for each option (based on the professional judgment of the authors as described above in Section 4.3).

4.0 Climate Change Risk Management Options

In general, it is recommended that all projects should include disaster preparedness measures, such as measures to issue timely and effective early warnings, evacuation and safety plans, and business continuity plans. A review of the insurance scheme is also recommended as a means to minimize post disaster losses. For new projects, selecting risk management measures during the feasibility and design phase can help avoid costly retrofits and maximize resilience to climate change impacts throughout the project life.

Table 1: Climate Change Risk Management Options for the **Agriculture Sector**

Table 2: Climate Change Risk Management Options for the **Energy Sector**

Table 3: Climate Change Risk Management Options for the **Tourism Sector**

Table 4: Climate Change Risk Management Options for the **Water and Sanitation Sector**

Table 5: Climate Change Risk Management Options for the **Urban Infrastructure Sector**

Table 6: Climate Change Risk Management Options for the **Transportation Sector**

Table 1. Climate Change Risk Management Options for the Agriculture Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How the Option Addresses Hazard**	**Relative Cost**	**Implementation Feasibility**
Sea Level Rise	Loss of arable land from inundation, or potential saltwater intrusion	Install levees to keep water out of desired farmed areas	Routes water away from field	$$$	Ranges from moderately easy to difficult to implement depending on the size of the levee
		Increase the quantity of irrigated water to reduce effect of salt load on crop	Decreases soil salinity	$$	Moderately easy to implement
		Where possible, reduce dependence on groundwater supply by using surface water where available	Reduces additional saltwater intrusion and allows irrigation by water of more suitable quality	$$	Difficult to implement; depends on availability of alternative water supplies and more efficient technologies
		Consider artificial recharge of groundwater to prevent salt water intrusion	Creates an artificial barrier to salt water intrusion	$$	Moderately difficult to implement
Storm Surge	Inundation of crops, possibly by saltwater	Move farmed areas inland; revert to more natural vegetation that provides storm surge protection such as mangroves and wetlands	Routes water away from field	$$$	Difficult to implement; large social costs
		Install levees to keep water out	Reduces potential for flooding	$$$, but depends on setting	Ranges from moderately easy to difficult to implement depending on the size of the levee
Hurricane winds	Damage to crops by wind	Use guide wires to protect large trees from high winds; build wind breaks; use alley-cropping	Provides extra security to prevent trees from falling over	$	Easy to implement
		Harvest early, if possible	Reduces crop losses	Depends on crop types	Easy to implement; may not be feasible for some crops
Flooding	Damage to Crops	Install pumping system to dewater fields	Removes standing water following a flood	$$	Moderately easy to implement
		Change type of crop to one that can handle temporary inundation (e.g. orchards, vineyards)	Reduces crop losses	Depends on crop type	Moderately easy to implement but the process takes time because of the establishment of new annual plants

4.0 Climate Change Risk Management Options

Table 1. Climate Change Risk Management Options for the Agriculture Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How the Option Addresses Hazard**	**Relative Cost**	**Implementation Feasibility**
		Restore coastal or riverine wetlands	Allows infiltration of flood waters and slow down of arrival	$$	Moderately easy to implement, depending on suitability of site conditions if site conditions allow
		Improve flood protection infrastructure (primarily levees or upstream dams)	Protects crops from flood	$$$$	Ranges from moderately easy to difficult depending on the type/degree of flood infrastructure
Drought	Damage to crops from reduced water and increased susceptibility to pests and disease	Increase irrigation efficiency of water used. Consider drip irrigation and similar higher efficiency methods.	Protects crops from drought by using water more efficiently	$$	Moderately easy to implement
		Use of treated wastewater for irrigation	Increases water availability for irrigation (water quality tolerance varies among crops)	$$$	Moderately difficult to difficult to implement, depending on whether there is wastewater treatment in place and social attitudes
		Develop institutional mechanisms, i.e. insurance to protect farmers from loss of production due to drought conditions	Provides financial support in the event of extreme events	$$$	Moderately difficult to implement
		Install deeper wells where adequate water supplies exist. Additional water catchments. This is typically a short-term emergency solution, especially if there is a long-term imbalance between supply and demand	Increases water supply and reliability	$$$	Moderately easy to implement; may not be feasible for some areas
		Explore alternative crops, and/or different varieties that are more resistant. Support research into crop characteristics that are more suitable for growth under warmer and drier conditions	Provides a long-term adaptation pathway	$$$	Difficult to implement; a long-term strategy, needs regional or international-scale cooperation

Table 1. Climate Change Risk Management Options for the Agriculture Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How the Option Addresses Hazard**	**Relative Cost**	**Implementation Feasibility**
		Use natural predators to reduce unwanted pests	Reduces potential damage to crops without chemicals	$	Moderately easy to implement; may not be feasible for some crops
Extreme temperatures	Damage to crops and loss of production	Develop institutional mechanisms to protect farmers from loss of production due to extreme temperature conditions (this also applies to drought conditions)	Provides financial support in the event of extreme events	$$$	Moderately difficult to implement
		Install blowers and shade to protect plants	Provides some cooling for plants	$	Easy to implement; may not be feasible for all areas
		Change type of crops, grow appropriate crop for new temperature conditions, timing and length of chill hours	Reduces crop losses	Depends on crop types	Feasibility is region-specific

4.0 Climate Change Risk Management Options

Table 2. Climate Change Risk Management Options for the Energy Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How the Option Addresses Hazard**	**What is the Relative Cost**	**Feasibility of Implementation**
Sea Level Rise	Facilities, e.g. ports and refineries, flooded and not accessible	In areas that are more vulnerable to flooding/storm surge because of rising sea level, install seawalls to prevent inundation	Protects facilities	$$$ depending on size	Ranges from moderately easy to difficult depending on the size of the seawall, could result in adverse impacts
		Install movable docks to accommodate variable sea levels	Maintains ability to transfer products	$$$	Moderately easy to difficult to implement, depending on capacity of proponent
		Update facility master plans to retreat from areas at risk of sea level rise and storm surge	Within a facility, where there is some flexibility, careful planning prevents creation of new assets in areas of higher risk		Easy to moderately easy to implement in pre-construction phases
		Elevate energy and transport infrastructure , like roadways, railways, pipelines, transmission lines	Protects ability to transfer products/access to facilities	$$$	Moderately easy to difficult to implement, depending on site conditions
Storm Surge	Damage to operations, and long-term damage to facilities from flooding	Install hardscape along levees or soft/green vegetation as buffer zone to prevent flooding	Protects facilities	$$$ depending on size	Moderately easy to difficult to implement, requires capacity (maintenance)
		Have emergency back-up pumping system	Provides the ability to dewater flooded areas following a storm surge event	$$	Easy to implement
		Move critical facilities to higher ground; elevate roadways/railways	Reduces flooding	$$$	Moderately easy to difficult to implement, depending on site conditions
		Install tide gate if on coastal river	Reduces tidal inflow	$$$$	Moderately difficult to difficult to implement; requires technical expertise and could result in adverse impacts
		Install barriers to route floodwaters away from facilities	Reduces flooding	$$	Moderately easy to implement; could result in adverse impacts

Table 2. Climate Change Risk Management Options for the Energy Sector

Hazard	Impact to Sector	Climate Change Risk Management Options	How the Option Addresses Hazard	What is the Relative Cost	Feasibility of Implementation
Hurricane Winds	Damage to buildings and exposed infrastructure by wind and flooding	Update building codes for appropriate hurricane risk categories in relevant region	Provides a higher standard for future design	$$	Ranges from easy to difficult to implement depending on scale; could require political will and new legal authority for community level changes
		Develop plans to identify weaknesses and protect existing infrastructure during hurricane (Continuity of Operations Planning)	Improves preparedness and attempts to limit damage during an event	$	Moderately easy to implement; requires capacity
		Add wind breaks along shore, such as vegetation or creating islands	Reduces impacts of hurricane wind	$	Moderately easy to implement; could result in adverse impacts
Flooding	Damage to buildings and subsurface facilities by flooding	Install barriers to route floodwaters away from facilities	Reduces flooding	$$	Moderately easy to implement; could result in adverse impacts
		Have emergency back-up pumping system	Reduces flooding	$$	Easy to implement
		Create a system of locks and barriers to prevent water intrusion into subsurface infrastructure	Limits damage to cables, transformers and related subsurface infrastructure	$$$	Moderately easy to difficult to implement; could result in adverse impacts
		Move critical facilities to higher ground	Protects critical facilities	$$$	Moderately difficult to difficult to implement, depending on site conditions
Drought	Reduced water for processing and cooling uses	Shift to dry cooling system for existing thermoelectric infrastructure	Eliminates water used for cooling process of power plants	$$$	Moderately difficult to difficult to implement; requires technical expertise
		Shift to renewable energy technologies such a solar photovoltaic and wind that require nearly no water	Removes processes that require water	$ (Many renewable energy technologies are cost competitive)	Moderately difficult to difficult to implement; depends on size of installation and state grid; integration in electricity system has to be secured

4.0 Climate Change Risk Management Options

Table 2. Climate Change Risk Management Options for the Energy Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How the Option Addresses Hazard**	**What is the Relative Cost**	**Feasibility of Implementation**
		Implement water recycling systems for municipal and industrial wastewater streams, such that these can be used as a source of cooling water	Reduces need for freshwater	$-$$	Depends on site setting and availability of wastewater streams
		Implement water conservation and recycling programs	Reduces need for freshwater	$-$$	Ranges from easy to difficult to implement; requires social and political will
Extreme temperatures	Less efficient cooling for power systems, reduced power production	Check efficiency of cooling system for power and air conditioning in buildings	Increases worker comfort and increases plant efficiency	$$	Moderately easy to implement
		Update design criteria for critical infrastructure to operate safely under higher temperatures	Allows for sustained operation during critical periods	$$	Moderately easy to implement
		Install Cool Roofs with reflective materials	Reduces energy requirements for cooling.	$	Moderately difficult to implement; requires technical expertise, capacity

Table 3. Climate Change Risk Management Options for the Tourism Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How the Option Addresses Hazard**	**Relative Cost**	**Feasibility of Implementation**
Sea Level Rise	Destruction of or damage to tourist structures and dependent structures (transportation, utilities, etc.) and loss of beach area to erosion	Elevate structure(s)	Removes and protects from major impact	$-$$	Easy to implement during design/construction; moderately difficult to implement after construction
		Promote development of natural protective features, such as wetlands and mangroves, in vulnerable areas; limit destruction of such areas where they currently exist	Mitigates storm surges that may be enhanced with rising sea levels	$-$$	Moderately easy to implement; could require social and political will
		Harden vulnerable coastline and protect coastal infrastructure using seawalls and breakwaters	Reduces inundated areas	$$$$	Difficult to implement; could result in adverse impacts
		Replenish beaches as a near-term solution	Temporarily counteracts loss of beaches from erosion	$$	Moderately difficult to implement; requires capacity, political and social will, could have adverse impacts
		Identify and develop alternative inundation safe transportation routes	Provides transportation routes	$	Easy to implement
		Re-site structure(s) or consider sea level rise risk in the siting and design of new structures; implement setbacks	Reduces exposure	$-$$	Moderately easy to difficult to implement, depending on site conditions; could require political will
Storm Surge	Destruction of or damage to tourist structures and dependent structures (transportation, utilities, etc.)	Elevate structure(s)	Reduces exposure	$-$$	Easy to implement during design/construction; moderately difficult to implement after construction
		Use breakaway walls[9]	Reduces damage potential from water	$$	Moderately easy to implement

[9] A breakaway wall is defined as "A wall that is not part of the structural support of the building and is intended through its design and construction to collapse under specific lateral loading forces, without causing damage to the elevated portion of the building or supporting foundation system." Refer here for definition and additional information: <https://www.fema.gov/national-flood-insurance-program/breakaway-wall>.

Table 3. Climate Change Risk Management Options for the Tourism Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How the Option Addresses Hazard**	**Relative Cost**	**Feasibility of Implementation**
		Re-site structure(s) or consider sea level rise risk in the siting and design of new structures	Reduces exposure	$-$$	Moderately easy to difficult to implement, depending on site conditions; could require political will
		Develop road closure map	Allows tourists to be moved safely	$	Easy to implement
Hurricane winds	Destruction of or damage to tourist structures and dependent structures (transportation, utilities, etc.) exposed to high winds	Use hurricane straps for houses/structures	Reduces damage potential from wind	$-$$	Easy to implement
		Shuttering	Reduces damage potential from wind	$$	Easy to implement
		Use hip roofs, secondary water resistance, and roof deck attachments (screws, large nails and tighter spacing) to keep roof on	Reduces damage potential to roof from wind	$$	Moderately easy to implement; requires technical expertise
		Identify evacuation route	Allows tourists to be moved safely	$	Easy to implement
Rising water temperature and acidity are (combined with pollution) a risk to coastal ecosystems	Ecosystems and reefs are a draw for tourism and any negative impact to them would result in a negative impact to tourism	Conservation efforts	Protects natural assets that may be a key source of the tourist arrivals	$-$$$	Moderately easy to difficult to implement; requires political and social will
Flooding	Destruction of or damage to tourist structures and dependent structures (transportation, utilities, etc.) in the flood inundation area	Elevate structure(s)	Removes it from major impact	$-$$	Easy to implement during design/construction; moderately difficult to implement after construction
		Use breakaway walls	Reduces damage potential from water	$$	Moderately easy to implement
		Re-site structure(s)	Reduces exposure	$-$$	Moderately easy to difficult to implement, depending on site conditions; could require political will

Table 3. Climate Change Risk Management Options for the Tourism Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How the Option Addresses Hazard**	**Relative Cost**	**Feasibility of Implementation**
		Redundant energy system	Reduces reliance on electric utility	$$	Moderately easy to implement
Drought	Water restrictions and extreme conditions have a negative impact on tourism and limit growth of tourism sector	Water catchment from roofs	Reduces reliance on water utility	$$	Easy to implement
		Low flow devices	Reduces amount of water consumed	$	Easy to implement
		Water conservation practices in facilities and landscape	Reduces amount of water consumed	$	Moderately easy to difficult to implement; requires social and political will
Extreme temperatures	Extreme conditions and no electricity/air conditioning have a negative impact on tourism	Redundant energy system; develop facility designs for greater cooling capacity	Reduces reliance on electric utility	$$-$$$	Moderately easy to implement
		Establish cooling centers[10] and air conditioning	Reduces potential injury to tourists	$-$$	Easy to implement

[10] A location that can be made available to the public as a cooling shelter during a heat wave.

4.0 Climate Change Risk Management Options

Table 4. Climate Change Risk Management Options for the Water and Sanitation Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How the Option Addresses Hazard**	**What is the Relative Cost?**	**Feasibility of Implementation**
Sea Level Rise	Saltwater intrusion to surface water and aquifers	Create a subsurface barrier using fresh or recycled water; this is not a structural barrier, but one created by lower salinity water injection	Decreases area affected by saltwater intrusion	$$$	Moderately difficult; opportunities are site-specific and could result in adverse impacts
		In freshwater intakes upstream of estuarine zones, sea level rise can raise salinity beyond acceptable levels, and intakes may have to be moved further upstream	Move pump intakes to freshwater zones with lower salinity	$$	Moderately difficult; opportunities are site-specific and could result in adverse impacts
		Manage fresh water flows to minimize salinization of lower elevation river reached and deltas	Ensures that a minimum quantity of freshwater is flowing through rivers to repel salinity from ocean water	$$$	Difficult to implement; requires flow control structure, such as a dam or reservoir to manage river flows, could result in adverse impacts
Storm Surge	Floods intakes and water supply facilities, Introduce stormwater with sediments and possibly saltwater to freshwater intakes; overload for wastewater treatment plants; combined sewer overflows	Install tide gates on major rivers	Prevents upstream movement of seawater	$$$	Moderately easy to difficult to implement; requires technical expertise and could result in adverse impacts
		Move water intake and treatment facilities upstream; harden facilities for impacts of larger flows and storm surges	Prevents flooding of water infrastructure	$$$	Moderately difficult; opportunities are site-specific and could result in adverse impacts
		Install barriers to route floodwaters away from facilities	Minimizes flood impacts to infrastructure	$$$	Moderately easy to implement; could result in adverse impacts
		Update facility master plans to retreat from areas at risk of sea level rise and storm surge	Reduces exposure	$	Moderately easy to implement; requires capacity
Hurricane winds	Damage to facilities by wind; power failures	Require enhanced building codes to handle higher wind speeds	Prevents structural damage	$	Ranges from easy to difficult to implement depending on scale; could require political will and new legal authority for community level changes

Table 4. Climate Change Risk Management Options for the Water and Sanitation Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How the Option Addresses Hazard**	**What is the Relative Cost?**	**Feasibility of Implementation**
		Install back-up generators to maintain pumping system	Prevents loss of pumping ability to route water	$	Easy to implement
Flooding	Flood intakes and water supply facilities, overflow of sewage pump stations; overload for wastewater treatment plants; combined sewer overflows	Install barriers or retaining walls to route floodwaters away from facilities	Routes water away from infrastructure to prevent flooding	$	Moderately easy to implement; could result in adverse impacts
		Move pumps and critical electrical infrastructure to higher ground	Keeps facilities on dry land	$$	Moderately easy to difficult implement; depends on site conditions
		Use flood waters to enhance recharge and supplement water supply	Uses excess flow for storage and, over the long term, enhance water supply	$$	Moderately easy to implement; could have adverse impacts
Drought	Reservoir and groundwater levels drop, decreasing water supply, increasing sedimentation	Implement water conservation programs	Reduces water consumption rates	$	Moderately easy to difficult to implement; requires political and social will
		Install deeper wells	Taps into deeper water supply	$$	Moderately easy to implement
		Install rain barrel collection devices and blue roof water collection system	Collects rain water for landscaping	$ to $$	Easy to moderately easy to implement
		Change pump intake locations in reservoirs or rivers	Moves pump intakes to deeper water	$$	Moderately easy to implement
		Reduce leakage in water networks	Reduces water losses, increases amount of water resources for supply	$$$	Moderately easy to moderately difficult to implement; requires technical expertise and capacity
		Use of treated wastewater	Increases freshwater availability	$$$	Moderately difficult to difficult to implement; could require political and social will, technical expertise
		Increase water storage capacity	Balances seasonal water shortage	$$$	Moderately difficult to implement; requires new infrastructure, possibly upstream

4.0 Climate Change Risk Management Options

Table 4. Climate Change Risk Management Options for the Water and Sanitation Sector

Hazard	Impact to Sector	Climate Change Risk Management Options	How the Option Addresses Hazard	What is the Relative Cost?	Feasibility of Implementation
Extreme temperatures	Loss of water in surface waters due to increased evaporation; increased likelihood of microbial contamination	Increase water withdrawals or supplement with other water sources	Replaces of lost supply	Variable but $$$	Moderately easy to difficult to implement; could have adverse impacts, require political will and new legal authority
		Avoid standing water resources in warm environments through increased flow	Protects against microbial contamination	$$$	Moderately easy to difficult to implement; could have adverse impacts

Table 5. Climate Change Risk Management Options for the Urban Infrastructure Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How the Option Addresses Hazard**	**What is the Relative Cost?**	**Feasibility of Implementation**
Sea Level Rise	Damage to private and public buildings	Move facilities further inland	Prevents flooding	$$$	Difficult to implement; could require social and political will, could result in adverse impacts
		Install barriers to route floodwaters away from facilities	Reduces flooding	$$$	Moderately easy to implement; could result in adverse impacts
		Elevate key facilities using new land or by raising level using wood/metal piling or using floating docks	Prevents flooding	$$-$$$	Moderately easy to difficult to implement, depending on site conditions
		Update zoning and local codes to minimize development and or promote retreat from very high risk areas	Provides growth and development in areas that are not highly vulnerable	$$-$$$	Moderately difficult to difficult; requires social and political will and new legal authority for community level changes
Storm Surge	Damage to buildings	Construct new building entrances at higher elevation	Provides safer entrance	$$-$$$	Moderately easy to implement
		Add hardscape to protect lower story of building	Protects building	$$	Moderately easy to difficult to implement, requires capacity (maintenance)
		Install back-up pump dewatering system for lower floors	Removes water before extensive damage done	$$	Easy to implement
		Install tide gates to prevent combination of high tide and runoff	Reduces potential flooding	$$$	Moderately easy to difficult to implement; requires technical expertise and could result in adverse impacts
Hurricane winds	Damage to buildings by wind	Install stronger roof	Prevents roof collapse due to wind	$$	Easy to implement

Table 5. Climate Change Risk Management Options for the Urban Infrastructure Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How the Option Addresses Hazard**	**What is the Relative Cost?**	**Feasibility of Implementation**
		Cover exposed components of infrastructure; other short term protective measures	Protects damage to buildings, and supports return to full use after event	$	Easy to implement
Flooding	Damage to buildings; water and sewage treatment facilities	Install barriers to route floodwaters away from facilities	Reduces flooding	$$-$$$	Moderately easy to implement; could result in adverse impacts
		Elevate key facilities using new land or by raising level using wood/metal piling or using floating docks	Reduces flooding	$$-$$$	Moderately easy to difficult to implement, depending on site conditions
		Install green roof instead of routing water to street	Uses some water to reduce volume routed to street	$$-$$$	Moderately easy to difficult to implement; requires technical expertise and capacity
		Use bioretention ponds to capture and infiltrate runoff	Allows more water to infiltrate and reduces runoff	$-$$	Moderately easy to implement
		Install sump pumps in basements	Removes water before damage to building occurs	$$	Easy to implement
		Move critical operations to higher floors (e.g. electrical, heat and cooling systems, communication)	Avoids loss of key equipment and enhances resilience after event	$-$$	Easy to implement during design/construction; moderately difficult after construction
Destructive fast onset events	Destruction of means of livelihood of the population / inhabitants	Have emergency shelters (designated zones or designated buildings) for the affected population	Reduces the impact on the population and enables quick disaster relief	$-$$	Easy to implement
		Have emergency response team available (equipment and trained staff) to do first repairs infrastructure	Decreases power outages and blocked roads	$$	Moderately easy to implement; requires capacity
		Have back-up food and water supplies for blocked or damaged areas	Decreases severity of emergency	$	Easy to implement

Table 5. Climate Change Risk Management Options for the Urban Infrastructure Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How the Option Addresses Hazard**	**What is the Relative Cost?**	**Feasibility of Implementation**
	Population could be stranded	Have evacuation plan	Accommodates elderly and disabled	$	Easy to implement
Drought	Damage to landscaping	Increase irrigation system efficiency to maintain landscaping	Reduces quantity of water used	$-$$	Moderately easy to implement
		Change plant mix to more drought tolerant plants	Reduces need for water	$-$$	Depends on site setting
	Limited access to water	Implement water conservation program	Reduces water uses	$	Moderately easy to difficult to implement; requires social and political will
	Limited access to water	Have back-up water supplies	Provides emergency water supply	$-$$	Easy to difficult to implement; depends on source of water
Extreme temperatures	Increased demand for heating and cooling	Plant trees for shade and to decrease heat island effect	Helps to decrease temperature	$	Easy to implement
		Install back-up generators to power heat/air conditioning systems	Allows heating and cooling systems to function after power failures	$	Easy to implement
		Set-up cooling centers for sensitive populations	Provides alternative respite place for people to shelter	$	Easy to implement

Table 6. Climate Change Risk Management Options for the Transportation Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How Does this Option Address Hazard**	**What is the Relative Cost?**	**Feasibility of Implementation**
Sea Level Rise	Flooding of airports, ports, and roads	Move facilities further inland	Moves facilities out of flood zone	$$$	Difficult to implement; requires social and political will and could result in adverse impacts
		Install barriers to route floodwaters away from facilities	Protects facilities from floodwaters	$$	Moderately easy to implement; could result in adverse impacts
		Elevate key facilities using new land or by raising level	Move roads, bridges, above expected sea level	$$$	Moderately easy to difficult to implement, depending on site conditions
		Develop alternative critical transportation paths	Provides resilience for events that occur infrequently (such as very high tides)	$	Moderately easy to implement; could result in adverse impacts
Storm Surge	Flooding of airports, ports, and roads	Use modular sea walls and flood walls along streets	Routes floodwater away from facilities	$$$	Moderately difficult to implement; could require social and political will and could result in adverse impacts
		Install pumping systems for low areas and underpasses	Reduces flooding	$$	Easy to implement
		Enhance building codes to increase setback distances	Reduces flooding	$	Ranges from easy to difficult to implement depending on scale; could require political will and new legal authority for community level changes
		Install tide gates to prevent combination of high tide and runoff	Reduces potential flooding	$$$	Moderately easy to difficult to implement; could result in adverse impacts
Hurricane winds	Damage by wind	Improve building codes to handle higher wind gusts	Prevents structural damage	$$	Ranges from easy to difficult to implement depending on scale; could require political will and new legal authority for community level changes

Table 6. Climate Change Risk Management Options for the Transportation Sector					
Hazard	**Impact to Sector**	**Climate Change Risk Management Options**	**How Does this Option Address Hazard**	**What is the Relative Cost?**	**Feasibility of Implementation**
		Install back-up generators to maintain pumping systems and other critical facilities	Prevents loss of ability to pump water, communication, and other critical operations	$	Easy to implement
Flooding	Damage to facilities, such as roads, bridges, bridge piers, and culverts from high flows and sediment transport; Possible roadway erosion through undermining	Improve levees along major rivers	Reduces flooding of roads near rivers	$$	Ranges from moderately easy to difficult to implement depending on the size of the levee
		Upgrade pumping systems to handle higher runoff for low areas and underpasses	Reduces impact of flooding	$$	Easy to implement
		Install walls to route floodwaters away from facilities	Prevents flooding	$$$	Moderately easy to difficult to implement; could result in adverse impacts
		Enhance infiltration systems such as using porous pavement or bioretention ponds	Reduces flooding	$$	Moderately easy to difficult to implement; requires capacity (maintenance)
		Install raised roads with rock-filled drainage ditches along the sides to increase infiltration	Reduces flooding of roads	$$	Easy to implement
		Armor bridge piers and culverts	Reduces impacts of floods and high sediment loads	$$$	Easy to implement
Drought	Damage to Landscaping	Install or modify irrigation system	Protects health of vegetation	$	Easy to moderately easy to implement, depending on site conditions
Extreme temperatures	Damage to Pavement by Buckling or Asphalt Softening	Increase maintenance for pavement surface	Covers spots where asphalt melted	$ to $$	Easy to implement
		Install concrete pavement to avoid problems with asphalt	Reduces holes in pavement	$$	Easy to implement

5.0 Considerations for Monitoring and Evaluation

Monitoring and evaluation (M&E) systems are used to guide the work of the Bank and ensure the IDB's social and economic development objectives are met. This section focuses on considerations for monitoring and evaluation at the project level.

Climate change risk management is a relatively new field, and few risk management strategies have been implemented much less tracked for effectiveness over time. Multi-lateral and development institutions are still at the early stages of developing M&E systems. Thus, these systems are not considered vigorous, with no "best practices" identified to date. This section does not provide ready-made indicators and metrics for project level risk management, but it does provide some ideas for establishing indicators, outputs, and outcomes for climate change risk management at the project level.

The overall purpose of M&E for climate change risk management is to establish a consistent process for tracking and reviewing the effectiveness of climate change project objectives or the climate change component(s) of a project. Specifically, it is important to identify what works and what does not work within the respective context of the project; to identify lessons learned and make adjustments to current and future activities.

It is helpful to first consider the objectives of climate change risk management to help identify the types of projects that could be considered as supportive of meeting those broader climate change risk management objectives. Lim et al., 2004 identify five climate change risk management objectives:

- Increase the robustness of infrastructure designs and long-term investments
- Increase the flexibility and resilience of managed natural systems
- Enhance the adaptive capacity of vulnerable groups
- Reverse trends that increase vulnerability
- Improve societal awareness and preparedness for future climate change

It is recommended that those projects where climate change is screened as potentially posing risk to development operations, either through direct impacts of climate on the project itself or indirectly through climatic factors adversely impacting the surrounding ecosystem or community through the project, are also considered for M&E.

An inherent issue when dealing with climate change is the long time horizon and uncertainty surrounding potential impacts. As a result of climate change, temperatures and sea levels are rising, precipitation patterns are changing, and hurricanes could intensify. Many of these changes are already occurring, and are projected to become more severe in the future. Climate change risk management will need to account for current climate variability as well as future climate change. Thus, M&E systems will need to consider both short- and longer term interventions. There is still a great deal of uncertainty regarding the rate of climate change and likelihood of potential impacts. M&E systems should be flexible to account for this uncertainty. For example, there is difficulty in defining success against the uncertainty of climate change impacts and moving baselines of climate change conditions (GEF, 2008). Additionally, there are no agreed upon standards or indicators of a 'successful adaptation project' given the relatively newness of climate change risk management (GIZ, 2011).

Given these challenges, an M&E system should therefore adhere to adaptive management principles, whereby adjustments can be made as new information becomes available. In the meantime, whatever monitoring process is used should include mechanisms that address the following key questions (adapted from Lim et al., 2004):

- Were climate change risk management strategies identified? Were the strategies endorsed by the borrower? Why or why not? What indicators demonstrate endorsement?
- Were the climate change risk management strategies implemented by the borrower? Were the strategies included in project feasibility and design and/or into the institutional processes? How did the strategies fit within the overall processes of prioritization?
- Was an M&E process institutionalized by the borrower? Did the borrower identify inputs for M&E such as sources of information and data, performance or process indicators, additional costs, and/or control mechanisms such as period of review or evaluation?

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