GREATER MEKONG SUB-REGION FLOOD AND DROUGHT RISK MANAGEMENT AND MITIGATION PROJECT

Consulting Services for Support to the National Flood Forecasting Centre and to Improve Hydraulic Design Standards

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CLIMATE RESILIENT DESIGN GUIDELINES
FOR
STRUCTURAL FLOOD AND DROUGHT CONTROL MEASURES

DRAFT REPORT

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Executive Summary

The Royal Government of Cambodia has received financial support from the Asian Development Bank to implement the Greater Mekong Sub-Region Flood and Drought Risk Management and Mitigation Project (GMS-FDRMMP), which is comprised of three components. Component 1.0 is to improve the National Flood Forecasting Centre (NFFC) and to propose climate resilient design guidelines for structural flood and drought mitigation.

This report presents climate resilient design guidelines for structural flood and drought control measures in Cambodia. The design guidelines consider the overview of flood and drought protection measures and details a comprehensive approach to flood and drought mitigation for Cambodia present in the Flood Protection and Drought Mitigation Measures Report (NFFC 2017). The role that climate change and land use change due to development and their effect on floods and droughts have been taken in to account during the development of the design guidelines for structural flood and drought control measures. The current thoughts on climate change and climate variability projections for Cambodia have been considered.

Considering the significant influence that land use changes on the flood plain will have, it is not appropriate to simply set a fixed structural standard. Therefore, the design guidelines for flood control measures outline a process, which uses a range of design flood criteria that considers the critical to non-critical nature of the infrastructure being proposed. The design flood event criteria consider risk, vulnerability, and climate change aspects with respect to the type of development planned.

Drought design guidelines are much more difficult to quantify and therefore the response and mitigation of drought impacts requires more of a non-structural approach. The management of drought in a defined area requires integrative approaches and integrated management, based not only on the natural features, but also on socio-economic conditions of the area. A framework for the timely implementation of drought mitigation measures and the adoption of an effective monitoring system for the evaluation of drought risk is proposed. Key to preparing for droughts is the ability to predict the potential for drought in a given season and its severity.

The report satisfies the deliverable for WBS 700,

Table of Contents

List of Acronyms and Abbreviations

ADB	Asian Development Bank
AusAID	Australian Agency for International Development
AWS	Automatic Weather Station
BDP	Basin Development Plan
CBDRM	Community Based Disaster Risk Management
CBOs	Community-Based Organization
CNMC	Cambodian National Mekong Committee
CSO	Civil Society Organization
DEM	Digital Elevation Model
DIS	Database and Information System
DHRW	Department of Hydrology and River Works
DOM	Department of Meteorology
DSF	Decision Support Framework of MRC
DTM	Digital Terrain Model
EIA	Environmental Impact Assessment
EWS	Early Warning System
FMMP	Flood Management and Mitigation Programme
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Greenhouse Gases
GMS	Greater Mekong Sub-Region
GMS-FDRMMP	Greater Mekong Sub-Region Flood and Drought Risk Management and Mitigation Project
GTZ	German Technical Cooperation
ICT	Information and Communications Technology
IDPs	International Development Partners
IPCC	Intergovernmental Panel on Climate Change
IRBM	Integrated River Basin Management
IWRM	Integrated Water Resources Management
M-IWRMP	Mekong Integrated Water Resources Management Project
MOWRAM	Ministry of Water Resources and Meteorology
M&E	Monitoring and Evaluation
MRC	Mekong River Commission
MRC-RFMMC	MRC Regional Flood Management and Mitigation Centre

NCDM	National Committee for Disaster Management
NFFC	National Flood Forecasting Centre
NGO	Non-Governmental organization
O&M	Operation and Maintenance
PEMSEA	The Partnership in Environmental Management for the Seas of East Asia
PIO	Project Implementation Office
RB	River Basin
RBO	River Basin Organization
RBU	River Basin Unit
RCPs	Representative Concentration Pathways
RGoC	Royal Government of Cambodia
SOP	Standard Operating Procedures
SSEPs	Shared Socio-economic Pathways
SRES	Special Report on Emissions Scenarios
TA	Technical Assistance
TSA	Tonle Sap Authority
WB	World Bank
WBS	Work Breakdown Structure
WMO	World Meteorological Organization
WUAs	Water User Associations

List of Figures

List of Tables

1. Introduction

1. The Royal Government of Cambodia (RGoC) has received financial support from the Asian Development Bank to implement the Greater Mekong Sub-Region Flood and Drought Risk Management and Mitigation Project (GMS-FDRMMP). Component 1.0 of the project has two objectives. The first objective is to strengthen the National Flood Forecasting Centre (NFFC) to better forecast floods and droughts and to enhance NFFC's contribution to regional data, information, and knowledge for the improved management of risks associated with floods and droughts. The second objective is to propose climate resilient design guidelines for structural flood and drought control measures in Cambodia. The results of this work will enable the RGoC to reduce the consequences of floods and droughts as well as to undertake measures to better design structural and non-structural measures with the objective of reducing the negative effects that these natural disasters cause.

2. This report focuses on the second objective, which is the development of climate resilient design guidelines for structural flood and drought control measures in Cambodia. The guidelines take into consideration the mechanics of the flood and drought systems in the region as well as projected climate change implications.

3. Natural hazards have drastic effects on Cambodia's population and pose a serious challenge for water resources management and poverty alleviation in the country. Flood and drought vulnerability is one of the most significant factors that must be considered when addressing poverty reduction and economic development in Cambodia. Efforts are being made to devise strategies that aim to decrease this vulnerability through improved natural disaster preparedness and flood and drought proofing coupled with climate adaptation strategies to reduce risks from floods and droughts. Lessening the impact of floods and droughts are key priorities for sustainable development, for ensuring the safety and prosperity of the population, and for maintaining environmental integrity.

4. The Lower Mekong basin has a complex floodplain where floods exhibit many positive benefits as well as have negative consequences. The complexity and role of the floodplain has a significant influence on the extent, duration, and storage of flood water. A comprehensive study conducted by the Mekong River Commission (MRC) under the Flood Management and Mitigation Programme (FMMP) from 2011 to 2015 through the FMMP Initial Studies Project provided valuable insight in to how the flood zones behave with respect to mitigating flood impacts. Accordingly, the findings of the FMMP study are used extensively in the preparation of the guidelines presented in this report related to floods.

5. Climate change projections for Cambodia indicate a wetter rainy season with a greater percentage of the total rain for the rainy season resulting from extreme events, and a dryer dry season with perhaps less rain but higher temperatures. Projected runoff is to be higher and sea level rise will have implications for existing flood prone areas. Cambodia is expected to experience a reduced number of intense cyclones. These climate change projections have implications for floods and droughts in Cambodia.

6. In addition to climate change, future development on the basin's floodplains will affect flood behaviour and flood risk in the Lower Mekong basin. Potential floodplain changes include the development of new infrastructure, increased population, changes to land-use, and a higher standard of living. The critical flood attenuation function of the Cambodian floodplain and the Tonle Sap Lake system is potentially threatened by floodplain development and loss of flood conveyance due to infrastructure. The Cambodian floodplain is currently much less developed than the Mekong delta and this potential for new floodplain development may have a significant effect on future flood risk and vulnerability. The raising of levees and roads, the installation of culverts and bridges, which restrict natural flood flow pathways, and the greater compartmentalization of flood water retention areas all have the potential to increase vulnerability and to affect flood risk.

7. Development and land use changes draw attention to the need for a more encompassing perspective in which structural measures and land use changes in response to social-economic initiatives must be considered. This perspective must not only consider how floods and droughts will affect these developments and initiatives and their need for protection, but more importantly must consider how these developments and initiatives will increase or decrease flood and drought vulnerability. This broader perspective considers both the structural and non-structural measures to reduce vulnerability to floods and droughts.

8. An important consideration with respect to floods in Cambodia is the transboundary nature of the Mekong River basin. Much of the floodwaters in Cambodia are derived from upstream countries, including Viet Nam. Therefore, effective flood and drought management hinges on regional cooperation, information sharing, and the development of region-specific solutions.

9. Given that some provinces in Cambodia may experience floods and droughts within the same season. building capacity and awareness are key components of a flood and drought mitigation and risk reduction strategy.

10. Given this complex setting, the role that climate change and land use change due to development and their effect on floods and droughts must be factored into the design guidelines for structural flood and drought control measures. Therefore, it is not appropriate to merely set a fixed structural standard. What is required is a process driven approach to addressing the design of structural measures to lessen the impact of floods and droughts. This process driven approach for considering flood and drought design requirements is presented in this report.

2. Climate Projections and Implications

11. The Intergovernmental Panel on Climate Change (IPCC) notes that in the coming decades, global average temperatures will increase, rainfall patterns will change, extreme weather events will become more severe, sea levels will rise, and numerous other environmental changes will occur (IPCC 2007). However, the degree of change varies because the climate change implications are based on a number of emission and development scenarios. The emission scenarios consider low, moderate, and high emission projections for a range of assumptions related to population growth, technological development, economic growth, and energy sources. This variability among scenarios accounts for the wide margin in predictions. A second layer of variability is due to the uncertainty associated with ecological feedback in the system. Uncertainty increases with the complexity of the system and as predictions move further in time along ecological and social processes.

12. It is important to note that the scenarios used in earlier climate change assessment reports were replaced with Representative Concentration Pathways (RCPs) for IPCC's Fifth Assessment Report (AR5) in 2014. The RCPs supersedes the Special Report on Emissions Scenarios (SRES) projections published in 2000. The RCPs consider four greenhouse gas concentrations, not emissions, trajectories adopted by the IPCC. The RCPs are consistent with a wide range of possible changes in future anthropogenic (human) greenhouse gas (GHG) emissions. RCP2.6 assumes that global annual GHG emissions measured in CO_2-equivalents peak between 2010-2020, with emissions declining substantially thereafter. Emissions in RCP4.5 peak around 2040, then decline. In RCP6.0 emissions peak around 2080, then decline. In RCP8.5 emissions continue to rise throughout the 21st century. The four RCPs have consistent socio-economic assumptions but these may be substituted with the Shared Socio-economic Pathways (SSEPs), which are anticipated to provide flexible descriptions of possible futures within each RCP. The RCPs and SSEPs are used for climate modelling and research. They describe four possible climate futures, all of which are considered possible depending on how much greenhouse gases are emitted and the actions taken to limit these emissions.

13. The average temperature in Cambodia has increased since 1960 by 0.8°C, and with it the frequency of unusually hot days and nights has increased (McSweeney et al. 2008). The climate models project a further 0.3 to 0.6°C increase by 2025 (MOE 2002). Modelled estimates put the expected warming at 0.7 to 2.7°C by the 2060's (McSweeney et al. 2008). The temperature increases are expected to be more severe from December to June.

14. All climate change models agree that rainfall in Cambodia will increase, but the magnitude of change is uncertain. Estimates of the increase vary from as little as 3% to as much as 35% (ICEM 2009). Models predict that the increase in rainfall will occur during the wet season, bringing more flooding, and that precipitation in the dry season will be unchanged or lower (Eastham et al. 2008). Rainfall is expected to increase more in the lowlands than in the highlands, with precipitation and flooding increasing predominantly in the central agricultural plains, which are already vulnerable to flooding and drought.

15. Climate change will bring more extreme weather events such as storms, heat waves, droughts and floods. Damage from intense cyclones has increased significantly in Cambodia in recent decades (Cruz et al. 2007) and may worsen as the intensity and maximum wind speed of tropical cyclones making landfall is projected to increase significantly for Southeast Asia. However, the total number of cyclones reaching landfall may be significantly reduced. Damages may still rise as the greatest impacts are caused by the most intense storms. Extreme rainfall associated with tropical cyclones is expected to increase by up to a third.

16. The projected sea level rise along the Southeast Asian coastline relative to 1986 to 2005 is expected to exceed 50 cm above current levels by 2060 and approach 100 cm by 2090 (World Bank 2013). It is important to note that the World Bank 2013 report developed its projections on a 4°C increase under a RCP8.5 scenario.

17. In summary, the climate change projections for Cambodia indicate a wetter rainy season with a greater percentage of the total rain for the rainy season resulting from extreme events, and a dryer dry season with perhaps less rain but higher temperatures. Projected runoff is to be higher and sea level rise will have implications for existing flood prone areas. Cambodia is expected to experience a reduced number of intense cyclones.

18. It is apparent that the floodplain system with the current infrastructure cannot absorb the increases in extreme floods that most of the climate scenarios indicate. Considering a 2060 design horizon. which provides a design life of some 40 years for infrastructure currently in the planning stage, sea level rise is expected to approach 0.5 m by 2060, which will increase water levels at Phnom Penh by some 0.2 m. Peak water levels at Phnom Penh for a 1:100 event is expected to approach 0.3 m for a moderate climate change scenario and over 1.2 m for the extreme scenario. The increase in water level for even the moderate scenario is expected to lessen the existing flood protection works to less than a 1:20 year event. The duration of flooding is predicted to be extended by 14 days for a moderate scenario.

3. Basic Principles and Concepts

19. Design guidelines for floods and droughts are incomplete without incorporating the concepts of resiliency, adaptation, and vulnerability. The common definition of these terms are as follows:

- **Resiliency** is the ability to recover from a negative event, such as natural hazards and a changing climate.
- **Adaptation** involves preparations beforehand and strategies for recovery and adjustment. Adaptive capacity refers to a community's capacity to create resilience infrastructure, to develop response systems, and to take action.
- **Vulnerability** is an assessment of adaptive capacity, sensitivity, and exposure. Sensitivity and exposure are both tied to socioeconomic and geographic elements that vary widely in differing communities and geographic regions.

20. Design guidelines must consider structural and non-structural approaches to addressing flood and droughts hazards, where these terms are defined as:

- **Structural measures** aim to reduce flood and droughts risk by controlling the flow of water. Structural measures range from engineered structures, such as flood defences, drainage channels, and storage dams to more natural and sustainable complementary or alternative measures such as wetlands and natural buffers.
- **Non-structural measures** are actions taken to mitigate flood and drought loss and damages through better planning and management of watershed development. Non-structural measures address flood and drought risks by building the capacity of people to cope with floods and droughts. Non-structural measures include activities such as having in place an early warning system, building and zoning codes, supportive policies and strategies, education and awareness initiatives, and institutional capacity.

21. Design guidelines for flood and droughts must consider the design life of structural measures. The longer the design life, the more important are the consequences of climate change and future developments in the floodplain.

22. Design guidelines for floods may be based on a standard design storm or protection level which considers the recurrence period for flood causing events. The level of protection may vary considering the importance of the facilities being protected, which can be designated as critical facilities and non-critical facilities. For example, hospitals, emergency control and response centres, and key transportation corridors and infrastructure are critical and require a higher level of protection. Major industrial and population centres will also require a higher level of protection given the significant economic and potential for loss of life and livelihood associated with these centres. As well, sources of significant toxic contamination from hazardous substance such as oil, pesticides, or fertilisers must be well protected or placed outside the flood zone.

23. Design guidelines are often based on a frequency analysis, which is a standard statistical procedure to assign the likelihood of occurrence to a flood or drought event. However, a basic assumption of the statistical analysis is stationarity. That is, for extreme flood or drought events the statistics do not change in time and past observations can be considered as representative of future observations. With a changing climate the assumption of stationarity may not be applicable and more advanced statistical methods that account for the non-stationarity are required. A number of studies in Europe and North America have shown that there is no linear relationship between precipitation and annual maximum flood scenarios. The studies also revealed that low return period floods are more sensitive to climate change than high return period floods. This is thought to be due to the degree of wetness of the watershed at different flood frequencies. That is, if the watershed is wet, the dynamics that produce higher floods in medium to large watersheds is less affected by changes in precipitation and more governed by the drainage network within the watershed.

24. The **consideration of risk** has also emerged as a key concept for the selection of actions related to disaster management and for the selection of appropriate design criteria. Risk is generally described as the probability of occurrence (Likelihood Level) of an adverse event multiplied by the consequences (Consequence Level) should the selected event occur at the location under consideration. Therefore, the risk that an event may have is a function of the event's likelihood of occurrence and the consequence of the event should it occur for the location selected. The severity or risk level associated with a flood or drought event can be categorised as low, medium, high, or extreme as illustrated by Figure 3.1. Using the severity or risk level an organization can identify areas at high to extreme flood or drought risk, for example, and focus their mitigation measures in these areas. Or, the risk matric can be used to establish the level of

Likelihood Level	Consequence Level				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	District A			District D	
Likely				District G	
Possible			District B		District E
Unlikely		District F		District C	
Rare					

Low Risk
Medium Risk
High Risk
Exreme Risk

protection required from flooding.

Figure 3.1: Example Risk Matrix considering the likelihood level and consequence level

25. As described above, a risk-based approach to the assessment of natural disasters considers the probability of a natural disaster occurring and the consequences or level of damages that are expected. Furthermore, the risk-based approach considered the concept of inherent risk and residual risk as a dimension of the risk assessment. Inherent and residual risk reflects whether risk controls are in place when assessing the consequences associate with a natural disaster. For example; for a selected level of flooding if controls are in place to address the flooding at the time of assessment, then the measure of risk is considered to reflect a residual risk. The concept of inherent and residual risk is further demonstrated in Figure 3.2 considering a number of flood mitigation and adaption strategies. The figure shows how the initial risk or inherent risk is reduced through a number of non-structural and structural measures. A similar risk base approach can be applied when considering drought mitigation and adaptation strategies.

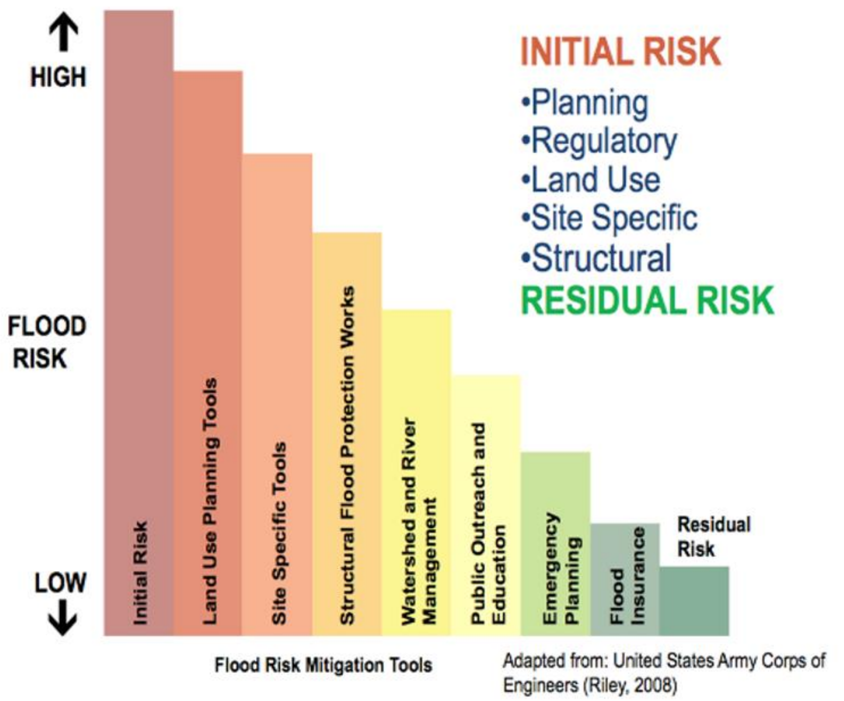

Figure 3.2: Residual risk considering non-structural and structural mitigation and adaptation measures

26. Flood risk assessment refers to the quantitative analysis of the level of flood risk for a river reach or basin as shown by Figure 3.3. The identification and mapping of flood risks requires information on flood hazard such as the extent and duration of flooding and the level of vulnerability in the area affected by flooding. Flood hazard analysis involves an analysis of flood occurrence, which considers meteorological events that may lead to flooding. As well, hydrological information such as peak discharges and volumes, as well as the characteristics of the river channel and floodplain are used to define flood events and flood extent. The flood hazard is defined in terms of inundation area, height of water, water velocity, and duration considering meteorological, hydrological, river channel, and floodplain characteristics. The level of risk is also related to the probability that a flood event of a specific magnitude will occur.

27. Drought risk assessment is generally more difficult to quantify and can vary depending on the type of drought such as:

- Meteorological drought, which is defined by low rainfall over the wet season (May to November)
- Hydrologic drought, which is described by relatively low amounts of water carried by rivers and streams, which can be the result of climatological conditions (low precipitation and high temperatures)
- Agricultural drought, which considers the effect of the reduced availability of soil moisture on crop yields, whether for food or fodder

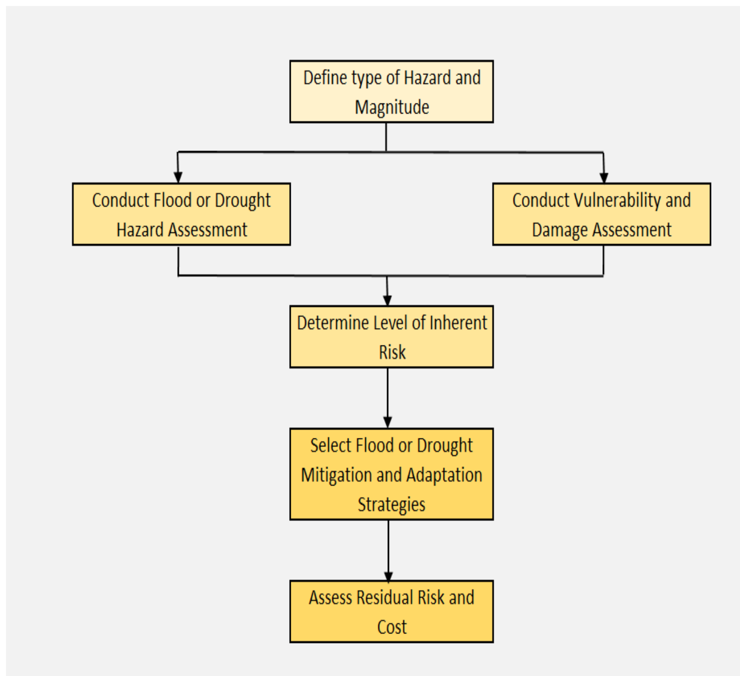

Figure 3.3: Risk assessment process

28. Meteorological, hydrological, and agricultural droughts are typically assessed through the analyses of a time-series of variables such as rainfall, stream flow, groundwater levels, and soil moisture data, on a variety of time scales. Drought is characterized by its intensity, duration, and spatial coverage. Intensity refers to the degree of the precipitation shortfall and the severity of impact associated with the shortfall. It is generally measured by the departure from normal and is closely linked to duration in the determination of impact. Another distinctive feature of drought is its duration. Droughts usually require a minimum of two to three months to become established, but then can continue for months or even years. The magnitude of drought is closely related to the timing of the onset of the precipitation shortage, its intensity, and the duration of the event. Droughts also differ in terms of their spatial characteristics, which can affect different areas from season to season. If the weather pattern persists for a short time over a few weeks or a couple months, the drought is considered short-term. But if the weather pattern becomes entrenched and the precipitation deficits last for several months to several years, the drought is considered to be a long-term drought. Often a drought index is used to display the severity and extent of droughts. Similar to flood risk assessment, drought risk assessment requires and understanding of the potential damages based on socio-economic-environmental data for the drought affected area. This information is used to build a vulnerability/damage model. Risk determination and drought risk mapping involves combining the results of the drought index analysis and the results of the vulnerability/damage assessment. The results can be displayed as risk maps, graphs, or risk numbers. The results provide an expected level of loss with an associated probability or frequency of occurrence.

29. **An adaptive approach** of "living with floods" and "living with droughts" is a strategic direction for flood and drought management in Cambodia. The approach considers the use of structural protection works by flood proofing of settlements and transportation infrastructure and the use and/or development of less vulnerable rice varieties to inundation. Drought adaptation approaches suggest greater use of low intensity irrigation, use of drought tolerant crop varieties, and greater use of water retention schemes and groundwater. Adaptation involves making adjustments in our decisions, activities, and ways of thinking in response to observed or expected changes, with the goal of reducing harm and taking advantage of potential opportunities. Adaptation involves preparations beforehand and strategies for recovery and adjustment. Adaptation can include behavioural changes, operational modifications, technological interventions, planning changes and revised investment practices, regulations and legislation. Policies, regulations and guidelines are mechanisms that can be used to raise awareness and encourage or require adaptive action. Planned adaptation takes time as it requires research, stakeholder engagement, and adjustments to policies and regulations. Many sectors are starting to use adaptive management approaches to deal with changes in climate and other stressors.

30. The concepts of risk and adaptation to natural hazards are important to understand when developing strategies and measures for flood and drought mitigation. Natural hazards, such as floods, droughts, extreme weather, and rising sea levels cause economic, social, and ecological loss by damaging property, by restricting access to food, by increasing the potential for disease, and by limiting the population's ability to earn a livelihood. Vulnerability is defined as a function of exposure, sensitivity, and adaptive capacity. In the context of vulnerability, exposure is the nature and degree to which a system is exposed to the natural hazard, and sensitivity is the degree to which a system is affected, either adversely or beneficially. Exposure and sensitivity are both tied to socioeconomic and geographic elements that vary widely in differing communities and geographic regions. Adaptive is defined as the ability of a system to moderate the potential damage from it, to take advantage of its opportunities, or to cope with its consequences.

4. Flood and Drought Mitigation Strategies and Measures

4.1. National Strategies

31. The Cambodian government has taken a multi-dimensional approach to flood and drought management. The approach uses both structural and non-structural measures to manage the risk and effects of floods and droughts. A National Early Warning Strategy and a Standard Operating Procedure (SOP) for the Flood Early Warning System was drafted in 2014 for the Cambodian National Committee for Disaster Management by the Asian Disaster Preparedness Centre through funding by the World Bank. The strategy addressed the need to conduct risk assessments and to develop early warning systems and building codes. The SOP for the flood early warning system defined the roles and responsibilities of the various government agencies involved in flood response.

32. The National Early Warning Strategy and SOP have been prepared from the perspective of how to respond to floods and droughts once they occur. Guidance and processes from the perspective of preparedness and adaptation are lacking as well as the development of standardizes building codes and land use zoning is limited. However, the limited availability of the standardized building codes, land zoning, and adaptation polices has not prevented the Cambodia government from undertaking structural measures to provide improved flood protection for larger centres and important transportation routes. Efforts to address drought events have been more difficult. Water retention and storage have been the predominate strategies used to date.

4.2. Structural Protection Measures

33. It is important to note that the Mekong floodplain and the Tonle Sap Great Lake system provides a critical flood attenuation and a drought mitigation function, which must be critically considered when developing flood and drought preparedness and adaptation strategies. Unplanned and uncontrolled development that threatens the storage capacity of the floodplain or the loss of flood conveyance will have long-terms consequences for efforts to reduce damages.

34. The most effective flood protection methods in Cambodia are relocation and elevation. However, when these methods are not feasible, structural flood proofing methods may be an alternative. Flood proofing is defined as any combination of structural and non-structural measures, which reduce or eliminate damages and loss caused by floods and droughts. Structural measures aim to reduce flood risk by controlling the flow of water. Structural measures range from engineered structures, such as flood defences and drainage channels to more natural and sustainable complementary or alternative measures such as wetlands and natural buffers. However, structural measures can be overtopped by events beyond their design capacity and result in significant damage and loss. As well, structural measures transfer flood risk by reducing flood risk in one location only to increase it in another location. Structural solutions have a high upfront investment cost, may induce complacency by their presence, and can result in a significant increase in damages if they fail.

35. Structural measures to address floods and droughts in Cambodia are typical focused on protection measures such as dams, dikes, and levees, and transportation corridor improvements by raising the elevation of road and rail lines. Building construction in urban areas is most often not flood proofed, whereas in rural areas it is common to have elevated living quarters. Structural measures related to droughts include reservoirs, flood water retention ponds, rainwater harvesting, irrigation, and wetland restoration. A number of flood and drought structural measures are shown in Table 4.1.

Table 4.1: Typical Flood and Drought Structural Measures

Strategy	Options
Reduce Flood Susceptibility	Dams and reservoirs
	Dikes, levees, and flood embankments
	High flow diversions
	Channel improvements
	Flood proofing
	Location of facilities
	Wetland Restoration
Reduce Drought Susceptibility	Dams and reservoirs
	Water retention ponds
	Irrigation
	Groundwater Use
	Wetland Restoration

4.3. Non-Structural Protection Measures

36. Non-structural measures are actions taken to mitigate flood and drought loss and damages through better planning and management of watershed development. Non-structural measures address flood and drought risks by building the capacity of people to cope with floods and droughts. As such, building capacity and awareness are key components of a non-structural flood and drought mitigation and risk reduction strategy. Non-structural measures include activities such as having in place an early warning system, building and zoning codes, supportive policies and strategies, education and awareness initiatives, and institutional capacity. Non-structural measures do not usually require large upfront investments, but rely on an improved understanding and awareness of floods and droughts, on an adequate forecast system, and on the affect population taking appropriate actions. Non-structural measures have four main functional elements as shown in Figure 4.1.

37. **Risk Knowledge** – Knowledge of the risk is gained through the conduct of risk assessments. The assessment of risk requires the systematic collection and analysis of data and considers the dynamic nature of flood and drought events and their associate vulnerabilities that arise from processes such as urbanization, rural land-use change, environmental degradation, and climate change. Risk assessments and risk maps help to prioritize flood and drought actions and to guide preparations for prevention, mitigation, and response.

Figure 4.1: Elements of Non-Structural Measures

38. **Monitoring and Warning** - Warning services lie at the core of the flood and drought mitigation system. There must be a sound scientific basis for predicting and forecasting flood and drought events and a reliable forecast and warning system. Continuous monitoring of flood and drought event parameters is essential to generate accurate warnings in a timely fashion. Warning services for flood and drought events must be coordinated and benefit from existing institutional, procedural, and communication networks.

39. **Dissemination and Communication** - Clear messages containing simple and useful information is critical in enabling proper responses from those at risk as well as to agencies responsible for flood and drought response and relief. Regional, national, and community level institutions must be identified and appropriate roles and responsibilities established well before any events occur.

40. **Response Capability** - It is essential that communities understand their risks, respect the warning service, and know how to react. Education and preparedness programs play a key role. It is also essential that flood and drought management plans are in place, well-practiced, and tested. Communities should be well informed on options for safe behaviour, available evacuation routes, and how best to avoid damage and loss to property and life.

41. Non-structural measures in Cambodia are continuing to evolve. Cambodia has a good understanding of the risk dimension and a number of risk assessments have been undertaken for floods, however few have considered droughts. Many of the studies advocate a 'living with the flood' strategy verse a structural approach. Forecasting and warning capacity is continuing to improve as well as the approach to communicate warnings and disaster information continues to improve and evolve to reach the community level much quicker. Mobile communications technologies and services are facilitating this change. The area requiring the greatest attention is awareness and appropriate response at the community level to flood and drought warnings. However, the level of awareness and knowledge of appropriate responses is

expected to increase significantly and in a short period of time as communications of the flood and drought conditions become more timely and comprehensive. A number of flood and drought non-structural measures are shown in Table 4.2.

Table 4.2: Typical Flood and Drought Non-Structural Measures

Strategy	Options
Reduce Flood and Drought Susceptibility	Catchment management
	Flood plain regulation
	Development and redevelopment policies
	Design and location of facilities
	Housing and building codes
	Flood and drought forecasting and warning
	Greater reliance on groundwater
	Drought tolerant crops
	Restoration of wetlands
Mitigate Impacts of Floods and Droughts	Information and education
	Disaster preparedness
	Post flood and drought recovery
	Flood and drought insurance
Preserve the Natural Capacity of Flood Plains	Flood plain zoning and regulations
National Flood and Drought Strategies	Coordination between governments and non-government organizations at national, provincial, and local levels

5. Flood Design Guidelines and Best Practices

5.1. General Considerations

42. Approaches to lessen the negative affect of floods in Cambodia consist of structural and non-structural measures. A number of studies for the region have raised caution with respect to the wide spread use of structural measures given the implications for loss of the natural floodplain function. The MRC Flood Management and Mitigation Programme 2011-2015 conducted a number of studies related to flood challenges and flood management strategies. The relative fragility of the flood control system for cities such as Phnom Penh and secondary towns such as Kampong Cham are highlighted by the results of the FMMP study. The report concluded that changes on the floodplain as well as climate change will have significant implications leading to higher flood water levels, longer duration of flooding, and increased flows.

43. The Cambodian floodplain and the Tonle Sap Lake system provide a critical flood attenuation function that is potentially threatened by floodplain development and loss of flood conveyance due to infrastructure. The raising of levees and roads, the installation of culverts and bridges to restrict natural flood flow pathways, and the greater compartmentalization of flood water retention areas all have the potential to affect flood risk and increase vulnerability. The Cambodian floodplain is currently much less developed than the Mekong delta and this potential for new floodplain development will have a significant effect on flood risk and vulnerability if it is not properly managed.

44. The possible footprint of Phnom Penh and other major towns along the Mekong River and around Tonle Sap Lake will continue to expand as the population increases and there is greater rural to urban migration due to better social-economic opportunities in the urban areas. The growing urban footprint has implications for increasing vulnerability due to the expansion of the densely-populated areas, which may be affected by flood water, as well as may significantly increase the damages that result from flooding due the higher density and higher valued properties and business located in urban areas. Urbanization of the floodplain will restrict the natural flood attenuation and normal flood pathways resulting in higher flood levels and longer periods of flood inundation outside of the urban areas. The mitigation measures for urban centre are often flood protection through the use of protections levels and dikes. While these structural measures are sufficient for less extreme flood events, they significant increase the urban centre's vulnerability to extreme events that exceed the design capacity of these protection measures resulting in catastrophic losses.

45. Therefore, it is important to recognise the role that development and land use changes have on floods and droughts. This recognition draws attention to a more encompassing perspective in which structural measures and land use changes in response to social-economic initiatives must be to consider not only from how floods and droughts will affect these developments and initiatives and the need for protection but, more importantly, how these developments and initiatives will increase or decrease flood and drought vulnerability. This broader perspective considers both the structural and non-structural measures to reduce vulnerability to floods and droughts.

46. The people of Cambodia have adapted to the occurrence of annual floods and are accustom to "living with floods" through adaptation, however rare and extreme flood events still result in significant loss of livelihood and damage.

5.2. Design Policies and Strategies

47. Adaptation is proposed as the core mitigation strategy, combined with selected and cautious use of structural measures.

48. The EU Floods Directive 9 2007/60/EC) requires that flood risks be addressed following a three-stage process. The first involves preliminary flood hazard mapping followed by a second stage requiring detailed flood hazard and flood risk mapping for critical areas identified during the preliminary mapping stage. The final and third stage involves the development of flood management plans.

49. A 'best practices document' for the EU was developed in 2003 as an update of the United Nations and Economic Commission for Europe (UN/ECE) Guidelines on Sustainable flood prevention (2000). The document identified a number of policy assumptions and principles that covered prevention, protection, and mitigation. The document noted the following key principles:

- Flood events are a part of nature. Floods have existed and will continue to exist. Therefore, in the future, human interference into the processes of nature that have implications for flooding should be understood and mitigated, as far as feasible.
- The flood strategy should cover the entire basin and promote the coordinated development and management of actions regarding water, land, and related resources.
- The flood strategy requires a shift from defensive action against floods to the management of the risk associated with floods that support a 'living with floods' adaptation strategy.
- Flood forecasting and warning is a prerequisite for successful mitigation of flood risk. Its effectiveness depends on the level of preparedness and correct response. The responsible authorities must provide timely and reliable flood warning and flood information.
- Human uses of floodplains should be adapted to the flood hazard. Mitigation and non-structural measures are more efficient and over the long term offer a more sustainable solution to reduce the vulnerability of people and goods exposed to flood risk.
- Structural measures (defence structures) remain important elements and should primarily focus on the protection of human health and safety, and valuable goods and property. However, flood protection is never absolute, and may generate a false sense of security. The concept of residual risk, including potential failure or breach, should be taken into consideration.
- Preparedness is a result of awareness, which is based on reliable and appropriate information that supports and enables individuals to plan, prepare, and react to flood events and reduce their risk and lessen flood damage.

50. Flood information and flood hazard maps must be available, widely disseminated, and explained. The information should be disseminated early and actively and be supported by media plans prior to and during a flood event. Flood hazard maps must identify areas at risk, be easily readable, and show the different hazard levels. Flood hazard maps are necessary for the coordination of actions, for planning, and for raising awareness.

51. Flood plains should be identified and designated by law to ensure development activities that threaten flood water retention and conveyance are easily known. The purpose is to discourage protective bank construction, embankments, impoundment and undermining, constructions or installations and, in general, any construction or works likely to form an obstacle to the natural flow of floods that cannot be justified by the protection of critical areas.

52. Information and education must be ongoing to ensure flood awareness is ingrained with the public. Flood marks placed in communities remind the public of the danger and are helpful for those not used to reading maps.

53. The most sensitive establishments, such as buildings, facilities, and installations whose operation is fundamental to civil safety, defence, maintaining public order, or whose failure presents a high risk to humans or are of socio-economic importance, must be implemented in no-risk-prone areas or protected and appropriate mitigation measures taken to address the loss of natural flood retention or conveyance capacity.

54. There is a need to implement a flood hazard risk assessment for all polices and developments activities proposed in a watershed. The flood hazard risk assessment will consider flood prevention and reduction measures as well as the provision of compensating flood retention areas.

5.3. Flood Design Process

55. The FMMP study of the Cambodian floodplain and Mekong delta highlighted the role of the floodplain in terms of conveying and attenuating flood flows. Floodplain storage is seen to be critical as a naturally functioning part of the river system that helps to reduce flood levels and downstream affects. Accordingly, changes on the floodplain as well as climate change will have significant implications leading to higher flood water levels, longer duration of flooding, and increased flows.

56. Given that storage and conveyance features of the floodplain have a direct effect on flood levels, extent, duration, and timing of flooding, a zone approached has been proposed that considers flood behaviour based on local natural influences and requirements. The FMMP study divided the floodplain into zones as adopted for WUP studies (WUP-JICA) and was modified slightly to provide a more comprehensive coverage of the full extent of the influence of flooding and flood considerations in Cambodia. The zones are shown in Figure 5.1.

Figure 5.1: Proposed Flood Zones

57. The flood design process follows the following steps:

Step One: Determine Design Flood Requirements

- Identify the Flood Zone and select design flood event criteria considering the planned development type as shown in Table 5.1. It is important to note that the 2000 flood is considered to represent the design flood for the 1:200-year flood event. The design flood event criteria consider risk, vulnerability, and climate change aspects with respect to the type of development planned.

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Table 5.1: Flood Design Criteria considering Flood Zone and Development Type

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
Zone C1 comprises the Great Lake and part of the connecting Tonle Sap River to Prek Kdam	This Zone contains the wet season maximum extent of the Tonle Sap Great Lake and Tonle Sap river floodplain to Prek Kdam and is a key part of the functioning of the natural response of the Mekong to the annual flood pulse. There are a number of significant provincial towns around the periphery of the flood season extent of the Tonle Sap Great Lake that are potentially at risk.	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection structures and embankments along main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment	• Design infrastructure considering the 1:20-year flood event or greater

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
		protected areas, changes to river channels, and river bank protection	• Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
Zone C2 lies on the Mekong right bank and Tonle Sap left bank and is bounded by the high ground to the north, Road 6 to the Prek Kdam bridge, and the Mekong to the south	Key features include the Provincial town of Kampong Cham and the Muk Kampul River which flows parallel to the Mekong eventually crossing the Road 6A and flowing back into the Tonle Sap.	All development should be limited in this Zone given the Zones importance for flood conveyance to the Tonle Sap Great Lake for significant flood events	• Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
Zone C3 lies to the south of Phnom Penh and to the west of the Bassac comprises of the region from Ta Khmau to the border with Vietnam, delimited to the east by the RN 21. There are some 90 artificial and natural colmatage canals transferring flood water from the Mekong/Bassac rivers to this zone through the RN 21. The population density is high along the Bassac river banks and the RN 21.	The area includes important wetlands and minor irrigation development. The Prek Thnot enters the Bassac at Ta Khmau, which is becoming part of the City of Phnom Penh as urbanization expands south. The border area is controlled by dike embankment along the right bank of the Vin Te canal in Vietnam and controlled openings to Zone V1 by two rubber dikes.	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigation
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
		irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas Proper planning and managements of colmatage canals to prevent excessive rise of water level in the areas.	flood level • Banned ground floor construction to prevent free flow constriction across RN 21 and Bassac river banks. • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection structures and embankments along main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Must identify transboundary impacts based on medium to long term development scenarios in Cambodia and in Vietnam
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to river channels, and river bank protection. Needs medium to long term planning supported by detail development scenarios integrated with other flood zones (C4, C7 and C8) to provide inputs for transboundary flood management and planning.	• Design infrastructure considering the 1:20-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Develop strategy for cropping pattern to reduce risk to flood and droughts taking into consideration of space for flood conveyance, storage and storage for dry season cropping
Zone C4 represents the Trans Bassac area is still under developed as compared to Vam Nao polder area in Vietnam but it is one of the least disturbed fishery ecosystem in the Mekong	The area is relatively underdeveloped except for the land along the banks of the Mekong and Bassac and in the vicinity of Road 1 that passes from Phnom Penh to Vietnam. There are four controlled colmatage canals crossing the RN1	All development should be limited in this Zone given the Zones importance for flood conveyance during significant flood events	• Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
floodplain and under increasing pressure from development.	between Kien Svay and Neak Leung and during flood season the flood water levels in the northern part of this zone are largely determined by the Bassac River and may be 1m lower than the Mekong side of the road. Roads are progressively being improved and raised and a major ring-road and bridge crossing of the Bassac has been opened defining the next stage of urban development close to Phnom Penh. Further south during flood season large part of flood water spill over the right bank of the Mekong into this zone to the flood zone C3. During the dry season and high tide period when flow from the Tonle Sap River stops, the Bassac River flows into the Lower Mekong River. With no waste water treatment facilities, this flow might similarly impact on water intake facilities on the Tonle Sap, the water intake on the Mekong.		infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigation • Re-establish, rehabilitate existing natural and artificial drainage channels in the areas connecting the Bassac with the back swamp and lakes
Zone C5 lies on the left bank of the Mekong River, is the largest maximum flood storage areas up to 8.6 MCM and during extreme flood receives more than 65% of the Mekong overbank flow.	The area is one of the key conveyors of floodplain flows via the Tonle Toch and associated floodplain areas. These include a number of flow paths including the lake at Prey Veng down to the connection of the Tonle Toch with the Mekong at Banam and Prek Kampong Trabek rivers spreading the Mekong overbank flow between Neak Leung and Kampong Trabek towns where RN 1 crosses the floodplain. Two important river branches drain this area namely the Stung Slot and the Prek Kampong Trabek.	All development should be limited in this Zone given the Zones importance for flood conveyance during significant flood events. An inter-sectoral strategy should be developed taking into consideration of its flow conveyance function, wetland ecosystem services, adaptable cropping patterns (early crop, recession crop and wet season crop) as basis for medium to long term spatial planning.	• Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Strategy for deep and shallow flooded areas development and

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
			management.
Zone C6 lies on the left bank of the Mekong River and is an area remote from the main flood areas of Zone C5 with mild maximum flood storage volume.	The area receives flow in time of high flood as water passes through culverts in RN 8 and RN 11 connecting to the West Vaico in Vietnam. It is also an area of localised flooding and source of water for Svay Rieng and other border areas. Large irrigation canals were built connecting with the Mekong flood water and with pumping during the dry season. Important area for ground water recharge for areas downstream, groundwater recharge facilities and management.	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance.	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Medium to long term plan scenarios development for transboundary impact assessment
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas. Reforestation and soil conservation improvements are required.	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection structures and embankments along main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
			• Retain deep flooded areas for ecosystem conservation and no protection during high flood and consider full protection for shallow flooded areas
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to river channels, and river bank protection and use of green engineering	• Design infrastructure considering the 1:20-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
Zone C7 lies on the left bank of the Mekong River below Neak Leung south of the RN1 and north of borders with Vietnam	The area is a key spill area on the left bank of the Mekong River. The Zone includes the Stung Slot and Trabek rivers and borders the Plain of Reeds in Vietnam (Dong Thap) and is one of the most important with respect to trans border concerns. Impacted by water management in Vietnam due to dike embankment along the Prek Smao/Soha Kaico along the border. (flooded land and water shortage for recession crops). Is experiencing decreased ecosystem services.	All development should be limited in this Zone given the Zones importance for flood conveyance during significant flood events. River navigation rather than road for bulk transport, river regulation with rubber dams for flow and tidal impacted water management Elevated or polders for restricted settlement areas	• Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • There is a concern with development restricting floodplain flow, which lowers important trans border flooding for Vietnam and increases flood levels upstream in Cambodia • Must identify the development impact on the flood level due to the loss of floodplain storage, flood conveyance and trans border flooding and mitigate • Develop medium to long term development scenarios to assess trans border impacts with other flood zones C8, C6, C3 and C4
Zone C8 is a trans border area to the east of Zone C7, severely flooded during the 2000 highest	The area is a trans border area and has significantly less floodplain flow than Zone C7. It is the source of the West	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors,	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
flood; acid sulfate soil, large barren land areas.	Vaico in Vietnam and flooding on the Cambodia side near the border is closely linked to the hydraulic conditions on the Vietnam side.	emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance, forest regeneration, reforestation, soil conservation, green technology	designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage, flood conveyance and trans border flooding and mitigate
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection structures and embankments along main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage, flood conveyance and trans border flooding and mitigate
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to river channels, and river bank protection	• Design infrastructure considering the 1:20-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage, flood

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
			conveyance and trans border flooding and mitigate • Develop medium to long term development scenarios to assess transboundary impacts with other flood zones C7, C6, C3 and C4.
Zone C9 contains the Mekong River from Kratie to the upper end of Zone C2 and C5 at Kampong Cham	The area has a limited floodplain extent on both side of the Mekong River not well connected and increasingly disconnected with the Mekong with road development along both river banks. The Kratie town is the uppermost location of the Mekong Delta, where the downstream water level start to back up once the water level at Kratie has reached the level above 18.0 m. At high stage large amount of flow bypasses the control of the Kampong Cham hydrological station and rejoints the Mekong at the northern side of the zone C5. During severe floods Kampong Cham town despite its dike embankment along the Mekong river bank will be vulnerable to floods from its western site. Furthermore, the bypass flows across RN 7 between Kampong Cham and Suong town can only pass through Moat Khmung bridge, where land encroachment upstream is intensifying.	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance Flood protection ring dike of the Kampong Cham town should be verified for its design frequencies. The failures of the dike would have dramatic consequences downstream, including Phnom Penh	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate. • Medium to long term development scenarios should be included in the overall Mekong- TLSGL floodplain development and management.
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection structures and embankments along

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
			main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to river channels, and river bank protection	• Design infrastructure considering the 1:20-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate

Step Two: Determine Level of Flood Hazard

- Consult the appropriate return period flood hazard map (NFFC 2017) to identify the location of the planned development and determine the expected level of the flood hazard.
- Assess the impact of the planned development's impact on the flood level due to the loss of floodplain storage, flood conveyance, and trans-border flooding considering the flood hazard as defined by the 1:200-year flood event.
- Major works such as roads, levees, irrigation embankments, and water management structures will require the configuration and calibration of a suitable flood hydrodynamic model to assess the effect of the planned development on local flood levels for the required design criteria.
- Propose mitigating measures to ensure there is no net loss of flood storage and flood conveyance.
- Advise National Mekong Committee of any trans-border flooding concerns.

Step Three: Establish Flood Protection Design Level

- Select the design level for flood protection works considering the maximum water level projected to the HATIEN MSL.
- For semi-critical and non-critical works add a freeboard of 0 3m to accommodate for waves, localized influences, and uncertainty in the reference level.
- For critical works add a freeboard of 0.6m to accommodate for waves, localized influences, and uncertainty in the reference level.

5.4. Continuous Improvement

58. Improvements to the Digital Elevation Models (DEM) of the flood zone is of critical importance to the reliability and accuracy of the flood hazard mapping process. The base DEM must have the required precision and must be kept current to reflect changes in the flood zone. Regular investments are required.

59. The use of hydrodynamic models is critical to the effective assessment of the flood hazard as well as the assessment of proposed development will have on floodplain storage, flood conveyance, flood extent, and flood duration. The establishment of a standard approach to hydrodynamic modelling as well as regular improvements is necessary.

60. A timely and reliable flood warning and forecast system, dependent upon consistent near real-time reporting of hydrometeorological data is one of the basic conditions for protection against and response to floods. The basic hydrometeorological data collection system must be well maintained and must provide adequate coverage. The use of satellite and global modelled products, key to the identification of severe and extreme weather conditions as well as to the provision of seasonal outlooks, is critical to a well-functioning flood warning and forecast system. The forecast system must be effective and this requires

regular updates to the modelling platform and the incorporation of new knowledge and science as it becomes available.

61. Information on flood flow distributions within the floodplains are extremely limited and available only for the period between 2001 and 2003 during the MRC's TSLV project. Their usefulness for hydrodynamic model calibration and validation are outdated. Intensive data collection is needed at least every five to ten years to be in line with physical land use and climate changes.

62. Trained and skilled staff are critical to a flood warning and forecast system as well as the flood hazard assessment and flood management activity. Staff must have the correct educational background, be well trained, and motivated to continuous improve their skills and the technical aspects of the flood warning and forecast system.

63. Institutional strengthening requires significant attention. In addition to the establishment of the NFFC for improved flood forecasting, there is an urgent need for strengthening institutional capacity for flood management and mitigation to support medium to long term spatial planning.

5.5. Public Engagement and Awareness

64. An effective flood management framework requires prevention activities prior to the event, response and mitigation activities during the event, and rehabilitation and recovery activities post event. Each of these key activities requires public engagement and awareness.

65. Prevention activities include structural measures such as dams, dikes, levees and diversions as well as non-structural measures such as flood plain zoning, development and management planning (integrated flood risk management, IFRMM or spatial planning), development policies, watershed improvements, and flood preparedness through planning, education, and awareness. During the event, flood response and mitigation activities encompass flood forecasting and the issuing of warnings, emergency relief, and evacuation. Post event rehabilitation and recovery involves financial support, resettlement, reengineering of protection works, and review of flood response plans, flood management systems, and institutional arrangements.

66. It is essential that communities understand their risks, respect the warning service, and know how to react. Education and preparedness programs play a key role. It is also essential that flood management plans are in place, well-practiced, and tested. Communities should be well informed on options for safe behaviour, available evacuation routes, and how best to avoid damage and loss to property and life.

6. Drought Design Guidelines and Best Practices

6.1. General Considerations

67. Drought can result in food and water shortages, loss of income, and higher levels of disease. In Cambodia, the occurrence of relatively moderate drought events has significant impact given the high level of vulnerability and limitations in the ability of rural people to cope with the impact of drought events. Under a normal year, typical rainfall distribution is from May to October with heavy rainfall from August to mid-October. A dry spell of about 2 to 3 weeks in July and August is typical. For reference, droughts may be classified as being a meteorological, agricultural, or hydrological drought as shown in Figure 6.1. In a year when the inter-monsoon dry period is extended longer an agricultural drought can occur. An agricultural drought may also occur as the result of a late start and early end of monsoon season. Droughts are damaging to agriculture, especially rice and domestic water supplies and can result in a total loss of crops, livestock, and fisheries. Given the relatively high frequency of moderate to severe drought in the Lower Mekong basin, the cost of droughts is significantly higher than the cost of flooding. As the climate warms, the cost of droughts is expected to increase and will continue to be greater than those of floods.

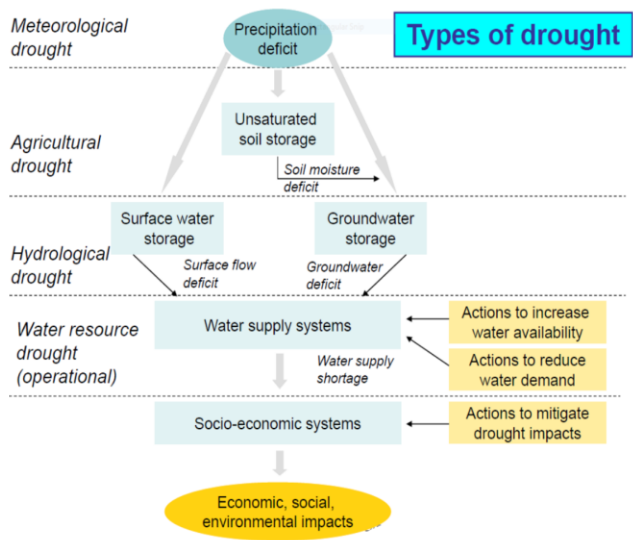

Figure 6.1: Drought Types

68. The implications of development and landscape changes on drought vulnerability are much less direct. Droughts are defined by the limited available of water to satisfy the social-economic and ecological needs of the region. Development may increase the demand for water and hence artificially increase the frequency of water shortages and the regions vulnerability to drought. However, drought is considered more of a naturally driven event, which is directly influenced by the natural climate conditions of the region and changes in rainfall and temperature patterns over the short to long term. The vulnerability of rural communities is increasing with loss of common properties, natural biodiversity, and wetland ecosystem resources that investment in water conservation and management are not able to resolve at this time as compared to decades before when these resources were abundant. Existing traditional mechanisms to cope with drought are becoming less valid today.

69. Climate change has a number of consequences for drought management in Cambodia. The consequences of climate change were derived considering the IPCC's Fifth Assessment Report and the investigations conducted under MRC's Flood Management and Mitigation Programme from 2010 to 2015.

There is general consensus that Cambodia and the Mekong River basin will experience increased rainfall during the wet season through more intense rain storm events. Rainfall during the dry season is expected to remain unchanged or be slight lower. The estimate for the magnitude of change varieties under the various climate scenarios, however the direction of the change is consistent. Temperatures during the dry season are expected to increase, which will have significant consequences for the increased potential of prolonged droughts.

6.2. Drought Policies and Strategies

70. While the people of Cambodia have adapted to the occurrence of annual floods and are accustom to "living with floods", they are less prepared for droughts that occur with a frequency of once in every three years.

71. The management of drought in a defined area requires integrative approaches and integrated management, based not only on the natural features, but also on socio-economic conditions of the area. Understanding the national institutional regime is a key factor for establishing effective and integrated drought management plans that incorporate monitoring, public participation, and contingency planning. A clear definition of roles and responsibilities among organizations and institutions are the basis for responsive and effective drought management plans and for improving future actions that mitigate the effect of drought on agriculture, water supply systems and the economy.

72. Considerable progress is being made in drought monitoring and early warning systems. The increased emphasis on improving these systems is largely the result of the mounting impacts of drought, reflecting greater societal vulnerability. Heightened monitoring capability, including the expansion of automated weather station networks and satellites are contributing to such improvements. In addition to improved monitoring, improved access to critical data and information continues with delivery of this information through a wide range of tools or decision support products to users in many sectors. Both the monitoring and availability of drought data has greatly assisted climate and drought assessments.

73. Adaptation is proposed as the core mitigation strategy, combined with selected and cautious use of structural measures.

74. Drought adaptation approaches suggest greater use of low intensity irrigation, use of drought tolerant crop varieties, and, greater use of water retention schemes and groundwater, water soil conservation. Considerations must be given to maintaining sensitive and valuable ecosystems such as forest cover, seasonally-inundated riparian forests; seasonal wetlands including marshes, small pools and pools; and seasonally inundated grasslands, agro-meteorological practices. These ecosystems are important as a habitat for a variety of fish and water birds and for the sustenance of the inland fisheries.

75. The vulnerabilities of drought are complex and have strong linkages between physical, social, economic and environmental conditions. A strategic plan for drought management must consider the Hyogo Framework for Action 2008-2015. According to the Hyogo Framework the strategy should follow five priorities:

- Strengthen institutional and technical capacities for drought risk reduction and climate change in agriculture and enhance coordination mechanisms
- Promote and enhance early warning systems for pro-active drought risk reduction and climate change adaptation
- Enhance knowledge management and innovation in support of drought risk management and climate change adaptation in agriculture
- Reduce vulnerabilities to droughts by improving technical options and implementing Community Based Disaster Risk Management and Climate Change Adaptation measures in agriculture
- Strengthen effective preparedness and response capacities including the integration of drought risk reduction and climate change adaptation into agriculture intervention approaches

76. National guidelines on drought management will reduce risk by developing better awareness and understanding of the drought and the causes of societal vulnerability. The principles of risk management will promote the building of greater institutional capacity through the improvement and application of seasonal and shorter-term forecasts, integrated monitoring and drought early warning systems and connected information delivery systems, developing preparedness plans at all levels of governance, adopting mitigation actions and programmes, and creating a safety net of emergency response programmes that ensure timely and targeted relief.

77. Watershed development programs entails the rational utilization of land and water resources for optimum production while causing minimum trauma to natural and human resources. Watershed management in the broader sense is informed by an undertaking to maintain the equilibrium between elements of the natural eco-system or vegetation, land or water on the one hand and human activities on the other hand. Watershed development provides the best environmental unit for planning a developmental program. The watershed development approach is an important facet of drought management initiatives.

78. Prevention and preparedness activities are designed to increase the level of readiness and improvement of operational and institutional capabilities for responding to a drought. Drought prevention and preparedness involve water supply augmentation and conservation such as rainwater harvesting techniques, expansion of irrigation facilities, effective dealing with drought, and public awareness and education. Transport and communication links are a must to ensure supply of food and other commodities during and just after a drought. Successful drought management requires community awareness on the mitigation strategies, insurance schemes for farmers, crop contingency plans, and economic relief mechanisms.

79. The overall development of the agriculture sector and the intended growth rate in GDP is largely dependent on the judicious use of the available water resources. While irrigation projects (major and medium) have contributed to the development of water resources, the conventional methods of water conveyance and irrigation are inefficient and have led not only to wastage of water but also to ecological problems such as water logging, salinization and soil degradation rendering productive agricultural lands

unproductive. It has been recognized that use of modern irrigation methods like drip and sprinkler irrigation must be considered as an alternative for the efficient use of surface as well as ground water resources.

80. Existing local traditional droughts managements systems and related social capital must be reinstated and strengthened as a national model before they are completely disappeared.

6.3. Drought Mitigation Process

81. Drought design guidelines are much more difficult to quantify and therefore requires more of a non-structural approach. Accordingly, droughts in a defined area require an integrative approach and integrated management based not only on the natural features, but also on socio-economic, institutional, and environmental considerations.

82. Long-term actions oriented to reduce vulnerability of water supply systems and short-term actions that are to be implemented during droughts are required. A framework for the timely implementation of drought mitigation measures and the adoption of an effective monitoring system for the evaluation of drought risk is required. Key to this is the ability to predict the potential for drought in a given season and its severity.

83. Drought management encompasses a number of vital components namely:

i. Plan for droughts events through actions such as:
   - Understanding drought vulnerability and how it varies temporally and spatially to establish comprehensive and integrated drought early warning systems as the result of water shortage and the exposure of the communities to water shortages
   - Developing a drought emergency plan
   - Developing criteria or triggers for drought-related actions
   - Developing a drought communication plan and early warning system to facilitate timely communication of relevant information to officials, decision makers, emergency managers, and the general public
   - Developing agreements for secondary water sources that may be used during drought conditions
   - Establishing an irrigation time/scheduling program or process so that agricultural land and priority crops receive the required amount of water at the required time
   - A definite cropping plan is required considering short duration varieties

ii. Develop drought indicators that identify the types and the severity of drought. The impact of drought has an environmental, economic, and social dimension and the indicator must capture these dimensions. Among the environmental indicators one could include, rainfall, water level in the reservoirs and other surface storage systems, ground water depth, and soil moisture.

iii. Develop drought prevention and preparedness measures that involve water supply augmentation and conservation, expansion of irrigation facilities, and public awareness and education. The use of integrate watershed management plans that encourages reforestation and maintenance of upland forest areas to preserve natural infiltration of rain water necessary to sustain base flow in upland tributaries is essential. Farmers should be encouraged to apportion at least 1% of their land holding for digging farm ponds. This will have a beneficial effect not only on tiding over the periods of drought due to lack of direct water availability but also help in recharging the local ground water table. A definite cropping plan will be designed for late sown crops with short duration varieties.

iv. Emergency response will always be a part of drought management, as it is unlikely that mitigation programs will anticipate, avoid, or reduce all potential impacts. As well, future drought events may exceed the "drought of record" and the capacity of a region to respond. However, it is necessary that there is a shift in public policy from drought relief to drought mitigation measures.

v. Develop community awareness and community leadership. Investments in disaster education, public awareness, and community leadership development must be encouraged. Communities need to be sensitized and to understand the importance of drought preparedness and mitigation.

84. The drought response process has the three stages:

i. **Pre-alert** - The management objective in the pre-alert stage is to prepare for the possibility of a drought. This involves public acceptance of measures to be taken if the drought intensity increases by raising awareness of the possible impacts due to drought. The measures that are taken in the pre-alert situation are generally of indirect nature, are implemented voluntarily, and are usually low-cost. The goal is to prepare for future actions. Responsible government agencies should increase monitoring, activate drought committees, and evaluate potential drought scenarios with special attention to worst case scenarios. With respect to the potentially affected communities, the focus is on communication and awareness. Generally, non-structural measures are taken, aimed to reduce water demand with the purpose of avoiding alert or emergency situations.

ii. **Alert** - The management objective in the alert situation is to overcome the drought by avoiding the emergency situation through the application of water conservation policies and mobilization of additional water supplies. These measures should guarantee water supply at least during the time span necessary to activate and implement emergency measures. The kind of measures that are taken in the alert situation are generally of a direct nature, require compliant by stakeholders, and generally have a low to medium implementation cost, although they may have significant impacts on stakeholders' economies. Most measures are non-structural, and directed to specific water use groups. Demand management measures include partial restrictions for water uses that do not affect drinking water, or water exchange between uses. There may be the potential for conflict as water users' rights and priorities under normal conditions are overruled, since water has to be allocated to higher priority uses.

iii. **Emergency** - The management objective is to mitigate impacts and minimize damage. Measures adopted in the emergency stage are of high economic and social cost, and they should be direct and restrictive. There may be the need for special legal statues for exceptional measures, which are approved as general interest actions under drought emergency conditions. The nature of the exceptional measures could be non-structural, such as water restrictions for all users including urban demand, subsidies, and low interest loans, or structural, such as new infrastructure, permission for new groundwater abstraction points and water transfers.

6.4. Continuous Improvement

85. Capacity building is a long-term phenomenon which has to be at the policy, implementation, Institutional, and individual levels. It also includes development of appropriate tools that will be used to convey useful information pertaining to drought. Capacity development generally encompasses various layers of governance by the national and provincial governments, district administration, and local authorities. Capacity building must address the needs of all the target groups of government functionaries. Components of the multi-layer capacity development framework include training, techno-legal framework, knowledge management, and developing organizational/ institutional and individual capacities.

86. Trained and skilled staff are critical to a drought warning and forecast system as well as the drought hazard assessment activity. Staff must have the correct educational background, be well trained, and motivated to continuous improve their skills and the technical aspects of the drought warning and forecast system.

87. A timely and reliable drought warning and forecast system, dependent upon consistent near real-time reporting of hydrometeorological data is one of the basic conditions for protection against and response to droughts. The basic hydrometeorological data collection system must be well maintained and must provide adequate coverage. The use of satellite and global modelled products, key to the identification of severe and extreme weather conditions as well as to the provision of seasonal outlooks, is critical to a well-functioning drought warning and forecast system. The forecast system must be effective and this requires regular updates to the modelling platform and the incorporation of new knowledge and science as it becomes available. Easy and transparent access to drought related forecasts and current conditions is critical. The establishment of a web based source, such as a drought management portal, is necessary.

88. Reliable and timely monitoring of hydrometeorological conditions using automatic weather stations is critical to defining and understanding the spatial extent and severity of drought. In addition to the typical suite of sensors the monitoring stations must also include moisture sensors for obtaining information about the soil moisture levels under natural environment. The use of remote sensing applications and modelled products are key to predict the potential and onset of drought conditions. Access to the data and information observed by the monitoring network via a dedicated webpage on drought monitoring and forecast is critical.

89. Long-term comprehensive hydrometeorological datasets of good quality are required to assess climate conditions, trends, and shifts as well as enable drought severity indexes to be developed and used effectively. Continued attention is required to quality control, maintenance, and the analysis of this dataset as well as to improve the tools and models used to predict drought and its severity.

90. Drought assessments must be current and consider vulnerability that reflects a communities' potential for water shortages and the exposure of the communities. Vulnerability maps are an important tool to understanding the impact and spatial extent that a drought will have.

6.5. Public Engagement and Awareness

91. An effective drought management framework requires prevention activities prior to the event, response and mitigation activities during the event, and rehabilitation and recovery activities post event. Each of these key activities requires public engagement and awareness. Prevention activities include structural measures such as dams, water retention ponds, groundwater exploitation, and rainwater harvesting schemes as well as non-structural measures such as drought response policies, watershed improvements, and drought preparedness through planning, education, and awareness. Drought response and mitigation activities encompass seasonal outlooks and the use of drought severity indexes for early warning, and planning emergency relief activities. Post event recovery involves financial support, resettlement, reengineering of drought mitigation works, and review of drought plans and drought management systems and institutional arrangements.

92. Developing a drought communication plan and early warning system to facilitate timely communication of relevant information to officials, decision makers, emergency managers, and the general public is key. It is essential that communities understand their risks, respect the drought warning service, and know how to react. Education and preparedness programs play a key role. It is also essential that drought management plans be in place, well-practiced, and tested. Communities should be well informed on options to mitigate the impact of droughts.

93. Spreading community awareness and developing community leadership for effective drought management is a critical step. Sensitizing communities is an important activity. Communities need to understand the importance of drought preparedness and mitigation. The is to promote an informed, alert, self-confident, and motivated community that will cope with the drought.

7. Summary

94. Floods, droughts, and extreme weather are the dominant hazards in Cambodia and cause loss of life, damage agricultural production, and threaten livelihoods. The occurrence of significant flood events and periods of droughts has increased in recent years. Climatic change predictions suggest there will be increased variability in the climate with an increase in the occurrence of more extreme weather events as the earth warms. The effect of an increase in extreme flood and drought events will directly affect vulnerable populations, exacerbate food insecurity, and result in an increase in related damages.

95. The Cambodian floodplain and the Tonle Sap/Great Lake system provides a critical flood attenuation function that is potentially threatened by floodplain development and loss of flood conveyance due to infrastructure and urban encroachment. The loss of the natural flood attenuation function through development on the floodplain can have significant consequences for increasing flood levels and duration. As well, the benefits of a natural flood cycle to fisheries, aquatic habitat, and the natural environment base economy can be substantial. Climate change is expected to further add uncertainty to the frequency and magnitude of floods and droughts in the region and the realization of more extreme weather. The projected sea level rise due to climate change will have a negative consequence for the Mekong Delta by increasing the base flood level.

96. Natural climate variability and anthropogenic climate change are drivers of weather and climate-related hazards, and that a range of socioeconomic processes are drivers of vulnerability and exposure. This framing is useful as it highlights that vulnerability and adaptation is not only about the occurrence of a natural hazard, but is about all factors that can interact to increase or decrease risk. An assessment needs to consider how climate change may alter the natural hazards to which a population is exposed, whether exposures are likely to change with increasing climate change, and the characteristics of the sectors and populations exposed to the hazard that can increase their risk. A consideration of risk is needed to be able to identify how modifying policies and actions could reduce the burden of negative outcomes. Furthermore, a consideration of risk helps in screening and prioritizing the full range of options available for reducing flood and drought risks.

97. Approaches to lessen the negative affect of floods and droughts may consist of structural and non-structural measures. A number of studies for the region have raised caution with respect to the wide spread use of structural measures given the implications for loss of the natural floodplain function. The MRC Flood Management and Mitigation Programme 2011-2015 conducted a number of studies related to flood challenges and flood management strategies. The findings of these studies hold true today and provide the bases for recommendations on refinements to the Cambodia's flood and drought risk mitigation strategy.

98. Adaptation is the core mitigation strategy that emerges combined with selected and cautious use of structural measures. Adaptation is a process through which societies make themselves better able to cope with natural hazards and an uncertain future due to climate change. Adapting entails taking the right measures to reduce the negative effects, or exploiting the positive ones, of natural hazards and climate

change by making the appropriate adjustments and changes. Adaptation options and opportunities range from technological options such as increased flood defences or flood-proofing houses, to flood and drought risk management through land use and zoning, to behaviour change such as reducing the use of water intense crops in times of drought. Other adaptation strategies include early warning systems for extreme events, better water and land management, improved risk management, insurance options, and biodiversity conservation. Planning in an adaptive way and building on a “living with floods” strategy is proposed as a strategic direction for flood and drought risk management in Cambodia.

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