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

ADB

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

Contract Number: GMS-FDRMMP-CS-003

PRELIMINARY FLOOD AND DROUGHT RISK ASSESSMENT 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.

The objective of this risk assessment report is to assist MOWRAM select "two priority basins" for piloting the flood forecasting and early warning system.

The report highlights the legislative, regulatory, and institutional context for flood and drought response and management in Cambodia.

The report provides an extensive review of previous studies and investigations of flood and drought events that have been experienced in Cambodia for the period from mid-1980 to present day. Information on the affects that these flood and drought events have had on human lives and livelihood, agricultural production, transportation routes, building infrastructure, and the overall economy is presented.

The results of the preliminary assessment clearly lead to the conclusion that floods and droughts affect a significant large area of Cambodia. Therefore, no one of two priority basins emerged from the analysis of the available data and information.

Given this result, basins vulnerable to both floods and droughts have been identified based on the review of studies and investigations noted in this report and the professional experience of the team. The river basins that are most vulnerable to floods and droughts were identified to be:

i. Tonle Sap Great Lake basin:
    - Stung Sen, Stung Siem Reap, Stung Sisophon, Stung Sangker, and Stung Pursat.

ii. 3S basin:
    - Tonle Sre Pok, Se San, and Se Kong.

iii. Prek Thnot basin.

iv. Mekong riverine and flood plain

Through consultations with MOWRAM, two basins have been selected as the study area under the NFFC project. The two basins are the Stung Pursat basin and the mainstream Mekong basin.

Accordingly, improvements for flood forecasts and drought predictions will be investigate for the two basins. However, due to the significant complexity of modelling and the significant area covered by flood events, the mainstream Mekong does not lend itself to the detailed assessment of flood and drought hazards and the associated assessment of risks within the twenty-four month available to complete the contract.

Therefore, the detailed investigation for the development of design guidelines for climate resilient structures will be limited to the Stung Pursat basin. It is believed that using the Pursat basin will not constrain, nor limit, the development, scope, and application of the proposed design guidelines.

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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
GFDRR	Global Facility for Disaster Reduction and Recovery
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
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
RGC	Royal Government of Cambodia
SOP	Standard Operating Procedures
TA	Technical Assistance
TSA	Tonle Sap Authority
WB	World Bank
WBS	Work Breakdown Structure
WMO	World Meteorological Organization
WUAs	Water User Associations

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1. Introduction

1. 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.

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5. The report discusses flood and drought risk assessment principles and applies these principles to identify basins with significant flood and drought risks. A summary of the severity and occurrence of floods and droughts for the significantly affected basins is presented.

2. Background

6. Some 86 percent of Cambodia's land area lies within the Mekong, Tonle Sap, and Bassac River basins. Given the low topography of these basins and the large fluctuation of water levels between the wet and dry seasons, Cambodia is prone to flood and drought events almost every year. As well, tropical storms also strike the country causing substantial damage.

7. The potential risks due to natural disasters are increasingly due to increased uncertain in the occurrence of significant meteorological and hydrological events, which have been attributed to climate change.

8. In particular, damaging floods and droughts are considered key barriers to economic, social, and environmental development and often result in human and livestock deaths. Natural (hydrometeorological) disasters in Cambodia are summarized in **Table 1**. The information is based on EM-DAT data, compiled by the Centre for Research on the Epidemiology of Disasters (CRED).

Table 1: Summary of natural disasters in Cambodia from 1980 to 2014

	Disasters	Number of Events	People Killed	Population Affected	Damage (000 US)
Drought	Drought	5	-	6,550,000	138,000
	average per event		-	1,310,000	27,600
Flood	Flood 1994	1	506	29,000	-
	average per event		506	29,000	-
	Flash flood	1	7	535,904	500
	average per event		7	535,904	500
	General flood	14	1083	12,055,758	1,418,600
	average per event		77	861,125	101,328
	Storm surge/coastal flood	1	-	124,475	-
	average per event		-	124,475	-
Storm	Tropical cyclone	3	44	178,091	10
	average per event		14.7	59,363	3

Source: EM-DAT - OFDA/CRED International Disaster Database (quoted from NCDM/ADPC 2014)

9. The following is a summary of the major hydrometeorological disasters (Source: ADRC) that have recently affected Cambodia:

- **2013 Flood**: In 2013, floods affected 20 of 24 provinces, 377,354 households, claimed 168 lives, and forced 31,314 households to evacuate to safe areas.
- **2012 Drought**: In August 2012, drought affected 11 of 24 provinces in Cambodia, 14,190 hectares of rice fields, and destroyed 3,151 hectares of rice seedlings. The hardest drought affected provinces were Kampong Speu, Takeo, Svay Rieng, Kandal, Prey Veng, Kampot, Battambang, Pursat, Banteay Meanchey, Uddar Meanchey, and Preah Vihear.
- **2011 Flood**: In 2011, a flood affected 350,000 households (over 1.5 million people) and 52,000 households were evacuated. The 2011 flood affected 18 of 24 provinces in Cambodia. Four provinces along the Mekong and Tonle Sap were worst hit. Some 250 people died and 23 people were injured as a result of the 2011 flood. As well, 431,000 hectares of transplanted rice were affected and 267,000 hectares of rice were damaged. Over 925 kilometres of the national, provincial, and urban roads were affected and 360 kilometres of the roads were damaged. The floods in 2011 caused an estimated loss of USD 630 million.
- **2011 Drought**: In 2011, drought affected 3,804 hectares and destroyed 53 hectares of rice.
- **2010 Drought**: In 2010, 12 provinces of 24 provinces were affected by severe droughts. Some 14,103 hectares of transplanted rice were affected and over 3,429 hectares of transplanted rice seedlings and 5,415 hectares of subsidiary crops were damaged.
- **2009 Typhoon Ketsana**: On 29 September 2009, Cambodia was struck by Typhoon Ketsana. Some 14 of 24 provinces were affected by the typhoon. The typhoon affected 180,000 households, killed 43 people, and injured 67 people.
- **2009 Drought**: In 2009, 13 provinces of 24 provinces were affected by severe drought. Some 57,965 hectares of rice crops were affected and 2,621 hectares were destroyed.

10. On average, annual damages and loss of wet season rice caused by floods and droughts is approximately 120,501 hectares, of which 70 percent of the damage and loss is due to floods and 30 percent is the result of droughts.

11. In can be seen from the summary information presented that flood and drought hazards are one of the most significant factors affecting poverty reduction measures and economic development in Cambodia. Moreover, the risks due to these hazards are expected to increase in the future as the result of climate change. Hence, flood and drought proofing and mitigation measures to reduce risks from floods and droughts as well as climate adaptation strategies are key priorities for sustainable development, for ensuring the health and safety of the population, and for maintaining environmental integrity.

2.1. Flooding

12. Flooding occurs frequently and extensively in Cambodia. The source of these floods can be the Mekong River including the Tonle Sap Great Lake, tributary flash floods, urban flooding, and failure of structures such as protection levee and storages.

13. Floods of the Mekong often raise slowly with significant lead times. Recent extreme floods on the Mekong affected Cambodia in 1978, 1991, 1994, 1996, 2000, 2001, 2002, 2011, and 2013.

14. The 2000 flood in Cambodia caused by the Mekong was reported as the worst in more than 70 years. It caused major disruption to the population, loss of life, and damage to infrastructure that was followed by major floods in 2001 and to a lesser degree in 2002. The official report compiled by the National Committee for Disaster Management (NCDM) dated 16 November 2000, put the death toll resulting for the 2000 flood at 347 of whom 80 % were children. Of the 750,618 families (3,448,629 individuals) affected by the 2000 flood, some 85,000 families (387,000 individuals) had to be temporarily evacuated.

15. Extreme flash floods occurred in 2007 caused by Tropical storm “PABUK” in earlier August, in 2009 caused by tropical storm “Ketsana” at the end of September, and in 2013 due to a tropical depression.

16. Urban flooding occurred in 2010 caused by tropical depression during 10-12 October in Phnom Penh and in 2011 in Siem Reap due to a tropical depression.

17. Even with the improvements implemented during the decade following the 2000 flood, Typhoon Ketsana in 2009 caused major damage. A series of heavy monsoon rains caused by tropical storms and a low pressure made 2011 the worst flood season in Cambodia since 2000. Flooding was caused by both flash floods and the Mekong flood event. Based on statistics issued by NCDM on 3 Nov 2011, the 2011 flood struck 18 cities and provinces. Kampong Thom, Battambang, Banteay Meanchey, and Siem Reap were the most affected provinces. The death toll was 250, over 1,593,976 persons or 354,217 families were affected, and more than 23,000 families were evacuated to higher ground. The magnitude and flood extent of the 2011 flood was less than the flood in 2000 (**Figure 1**), but caused more damage than the 2000 flood.

18. Damage related to floods in September and October 2013 caused 356 million dollars of damages, affecting some 370,000 households, destroyed over 125,000 hectares of rice crops, damaged 440 kilometres of national roads, and caused 168 people to lose their lives.

19. Given that flood losses are significant and frequent in Cambodia, flood management and mitigation policies supported by a comprehensive and effective flood warning system is critical to reducing flood impacts and losses.

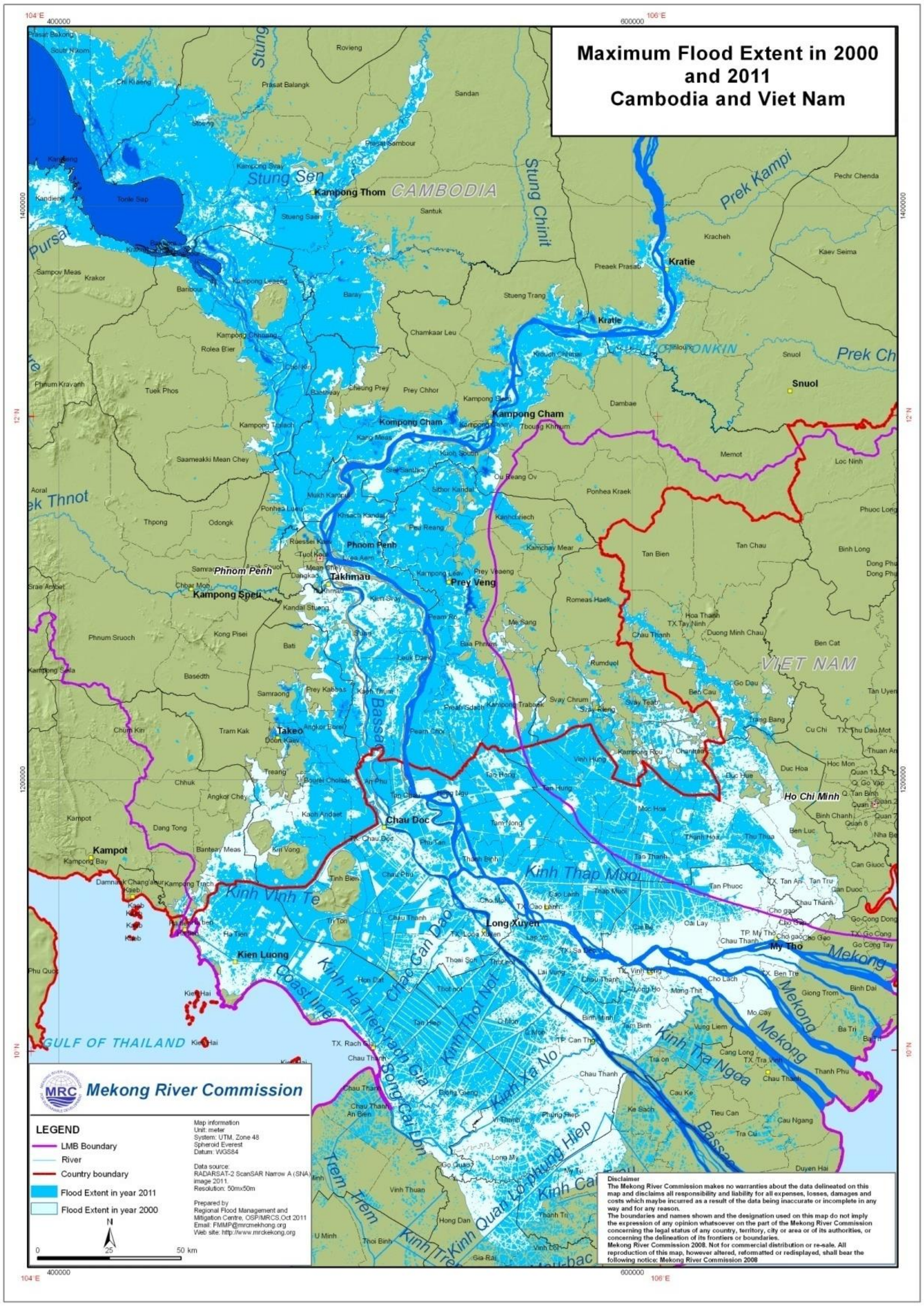


Figure 1: Comparison between 2000 (white) and 2011 (light blue) max flood extent in Cambodia.

2.2. Drought

20. Drought in Cambodia is usually associated with crop production as most agricultural production is from rain fed cropping. Over the last 25 years there have been a significant number of distinct drought events, occurring in 1986-87, 1994, 1997-98, 2001, 2002, 2004, 2005, 2009, 2011, 2012, 2014, and 2015.

21. According to drought studies (NCDM, 2006), Cambodia experienced a prolonged drought in 1997 to 1998 and had consecutive prolonged droughts in 2001, 2002, 2004, and 2005.

22. The term 'drought' typically refers to the situation when water availability is much reduced from the expected norm. Drought may be manifested in different forms, such as a meteorological, hydrological, and agricultural drought. These different forms of drought may or may not be coincident:

- Meteorological drought occurs when rainfall over a prescribed period is significantly less than the long-term average.
- Hydrological drought occurs when water resources are significantly depleted because of meteorological conditions. For example, stream flow for a prescribed period are significantly less than the long-term average.
- Agricultural drought occurs when meteorological and/or hydrological conditions reduce crop yields and affect livestock and fisheries production. An agricultural drought from a crop production perspective occurs when soil moisture is insufficient to meet crop water requirements. However, the actual reduction in crop yield depends on the type of crop, its growth stage, and the water holding properties of the soil. From a fisheries and livestock production perspective, an agricultural drought occurs when the supply of water and/or the condition of the water are inadequate to maintain normal growth.

23. Drought originates as a lack of rainfall. A series of dry days are not usually problematic. Rather it is the persistency of periods with lower rainfall that gives rise to a long-term rainfall deficit. The magnitude of the rainfall deficit is related to what would normally be expected, which depends on the season and region.

24. Cambodia receives most of its rainfall from the southwest monsoon, which takes place from mid-May through to the end of November. The coastal regions receive the highest rainfall, about 3,000 mm per year, while the highlands and lowlands receive on the order of 2,500 mm and 1,400 mm per year, respectively.

25. There are two 'dry' areas in Cambodia that are highly susceptible to drought. The Cardamom and Elephant Mountains of southwest Cambodia create a rain shadow, leading to an area of reduced monsoon rainfall in the southeast of Cambodia. Similarly, the rain shadow cast by the Phang Hoei Range limits rainfall across northeast Cambodia.

26. Droughts tend to be triggered when the wet season rainfall is much lower than normal. Lower than normal rainfall is usually associated with a much shorter wet season. A shorter wet season is caused when the onset of the wet season is delayed, or when the wet season ends earlier than normal. As well, drought

can result from a number of consecutive drier weeks (dry spells) within the wet season. Normally drought or dry spells occur during July and/or early August. Short droughts typically last for about 15 days, but occasionally can last up to 60 days after the first monsoon rains.

27. According to the Ministry of Environment, the worst drought years were recorded in 2002 and 2004. The drought in 2002 affected 43 districts in eight provinces (**Figure 2**). Some 442,419 families (2,017,340 individuals) were affected. The total estimated damage was US$ 9 million. According to FAO and WFP reports, the 2004-2005 drought affected 14 of 24 provinces. Rice and crop production was affected in all provinces and about half a million rural people faced food insecurity.

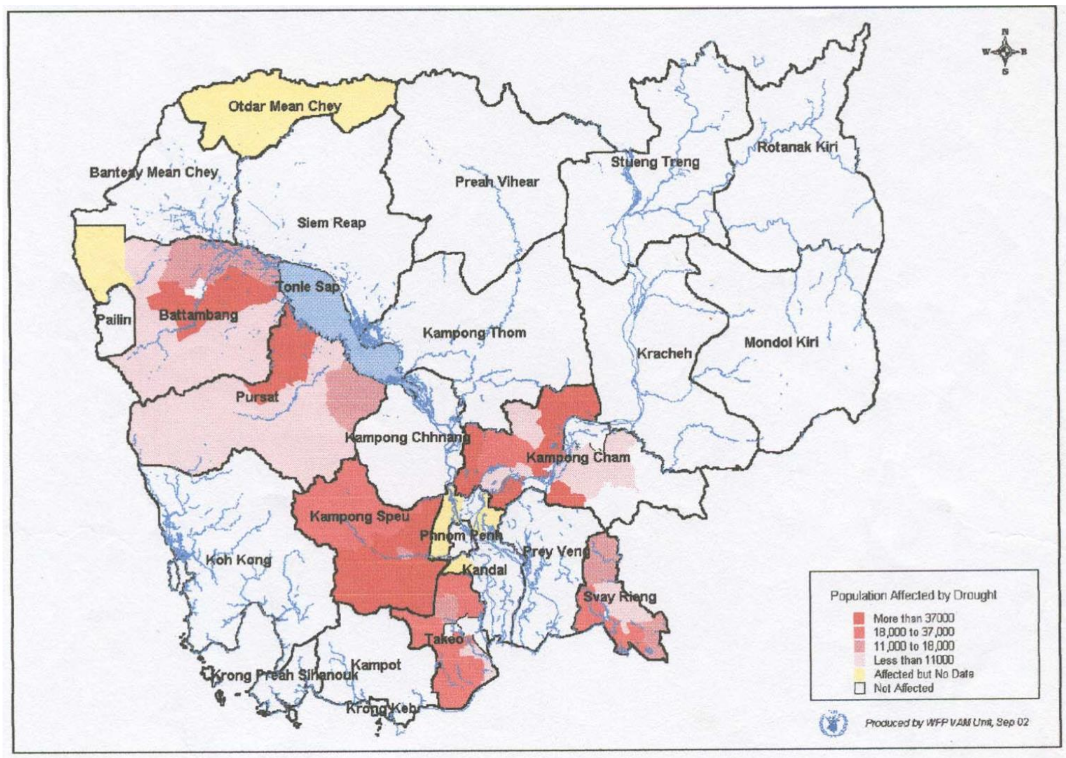


Figure 2: Provinces and population affected by the 2002 drought

28. Given that drought losses are significant and frequent in Cambodia, drought management and mitigation policies supported by a comprehensive and effective drought prediction system is critical to reducing drought impacts and losses.

2.3. Legal and Administrative framework

29. In response to the need for better coordination and facilitation in coping with the occurrences of disaster events, the Royal Government of Cambodia (RGC) established the National Committee for Disaster Management (NCDM) in 1995. The NCDM is the lead coordinating agency that has the responsibility for disaster risk reduction, mitigation, preparedness, response, and recovery. The Prime Minister chairs the

Committee with members representing 22 government ministries and agencies such as Economics and Finance, Agriculture, Forestry and Fisheries, Water Resources and Meteorology, Rural Development, Health, Defence, and Police as the key members. The NCDM is replicated at lower governmental levels. Each province has a Provincial Committee for Disaster Management (PCDM), and each district has a District Committee for Disaster Management (DCDM). These committees are chaired respectively by provincial governors and district chiefs. The committee members are local representatives from government line ministries and agencies. The system operates at the commune level with the Commune Committee for Disaster Management (CCDM) and Village Disaster Management Team (VDMT) for the implementation of Community Based Disaster Risk Management (CBDRM).

30. The NCDM key functions and responsibilities are:

- Management of data on disaster risk and the reporting on disaster situations;
- Proposing the level of resource reserves for disaster interventions and emergency responses;
- Providing capacity building and human resource development on disaster management;
- Coordinating and implementing disaster management policies;
- Exchanging and sharing information; and
- Coordinating and mobilizing resources for disaster response.

31. The NCDM plays a key role in coordinating various NGOs, development partners, and CSOs that are working in various parts of the country. NCDM leads the coordination of a CSO DRR Forum, which is comprised of the CSOs and NGOs operating in Cambodia.

32. The United Nations Disaster Assessment and Coordination Team (UNDAC) report (March 2009) concluded that the DCDM and CCDM have capacity to deal with relatively small-scale floods and disasters.

33. The Royal Government of Cambodia (RGC) has given particular attention to disaster management by adopting the Hyogo Framework for Action (HFA) as an instrument for the promotion and improvement of disaster risk reduction. In implementing the HFA, the Royal Government of Cambodia developed a Strategic National Action Plan for Disaster Risk Reduction (SNAP-DRR) covering the period 2009-2013. It includes six major components as follows:

I. Ensure disaster risk reduction and preparedness for emergency response from the national to grassroots levels;

II. Strengthen the management of disaster risks and preparedness for emergency response at the sub national and community levels;

III. Identify, assess, and monitor disaster risks and enhance early warning systems;

IV. Use knowledge, experience, and education to build a culture of safety and resilience at all levels;

V. Mainstream risk reduction in policies and programs of all ministries and institutions; and

VI. Strengthen preparedness for effective response to disasters at all levels.

34. A significant achievement was that disaster management in Cambodia was integrated into the Strategic National Development Plan for 2009-2013 based on the achievements and challenges experienced form implementing the 2006-2010 Strategic National Development Plan. The 2009-2013 Plan clearly identified that natural hazards such as floods, droughts, typhoons, and epidemics caused risk to human lives, damaged agricultural crops as well as properties of people, and impacted the overall economy of Cambodia. The Key Policy Priority and Actions for 2009-2013 of the Strategic National Development Plan were focused on implementing the Strategic National Action Plan for Disaster Risk Reduction (SNAP-DRR) 2009-2013 through the strengthening of participatory mechanisms and effective coordination with all stakeholders.

35. As well, a number of supportive strategic and action based plans have been enacted, which support Disaster Risk Management in Cambodia, such as:

- National Action Plan for Disaster Risk Reduction 2014-2018 (drafted and adopted in 2014);
- Community Based Disaster Risk Management Plan (CBDRM);
- National Contingency Plan for Flood and Drought (under review);
- MOWRAM's Strategic Development Plan 2014 – 2018; and
- MOWRAM's two Sub-decrees on Farmer Water Utilisation Committees (FWUC), on River Basin Management), and another two Sub-decrees (under review) on Water Licensing and on Water Quality Management.

36. Structural measures for flood and drought management are under the responsibility of the Ministry of Water Resources and Meteorology (MOWRAM), which are implemented and operated through the Provincial Department of Water Resources and Meteorology (PDOWRAM). MOWRAM is responsible for the planning and implementation of large-scale infrastructure investments, whereas PDOWRAM are delegated the planning and implementation of smaller scale infrastructure projects, particularly at the commune level. Flood and Drought Management is one of MOWRAM five strategic areas in the Ministry's Strategic Development Plan 2014 – 2018. The total of US$ 283 million is needed to be invested during that 5-years period: US$ 0.2 mill. is the governmental in-kind contribution and the rest of US$ 282.8 mill. is sought for the International development partners (IDPs).

37. Studies of the institutional arrangements for flood and drought management in Cambodia have concluded that Cambodia requires an institutional framework to address flood and drought risks in a comprehensive manner considering both structural and non-structural measures. These studies have suggested that MOWRAM and NCDM need to have clearly defined mandates with respect to roles and responsibilities for flood and drought disaster management. For example, NCDM should be responsible for overall policy coordination and policy guidance for flood and drought management and national response and coordination, whereas the implementation responsibilities would be assigned to the PCDM to facilitate a multi-sectoral approach. Under this framework MOWRAM would support large-scale infrastructure investments, which may cover more than one province, whereas the PDOWRAM would undertake priority structural measures, particularly at the commune level in collaboration with the PCDMs, DCDMs, and CCDMs.

3. Assessment Objective and Scope

38. The genesis for this assessment report was to guide the selection of "two priority basins" for the conduct of the Component 1.0 activities to pilot the flood forecasting and early warning system and for the development of climate resilient design guidelines for structural flood and drought mitigation.

39. However, the need to use the report to guide the selection of "two priority basins" has been overtaken by MOWRAM's decision to identify the priority areas for the project based on their knowledge, their desire to see collaboration between components of the GMS-FDRMMP project, and their need to improve the flood and drought forecast system for critical and high risk areas in Cambodia. Consequently, MOWRAM has identified the Pursat basin and the mainstream Mekong as the priority areas for Component 1.0 activities.

40. However, it is believed that a summary report on flood and drought event, risks, and impacts would provide useful information for guiding the activities of Component 1.0 and would expand the available knowledge on flood and droughts implications for Cambodia.

41. Hence, information on the location, type of event, extent and duration of the event, as well as statistics on the impact that past floods and droughts have had on communities, human health, economic activity such as rice production, cultural heritage, and the environment, has been summarized in this report.

42. The framework for the assessment and presentation of flood and drought events is based on the thirty-nine river basins as defined by MOWRAM in its sub-decree on river basin management. The thirty-nine river basins are shown in **Figure 3** and the basin areas for each of thirty-nine basins are summarized in **Table 2.**

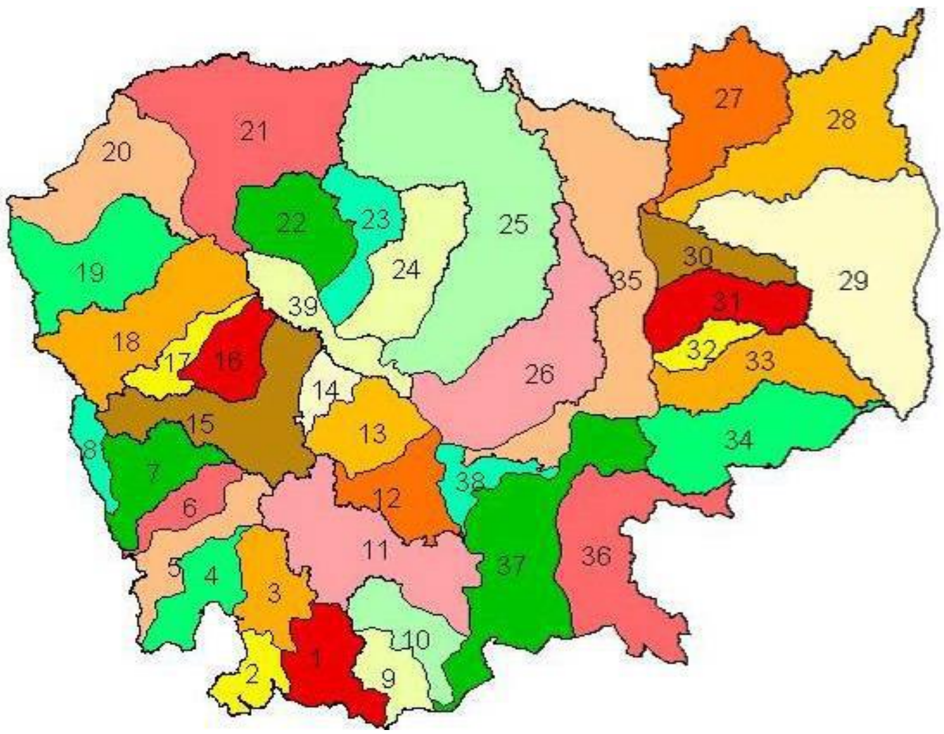


Figure 3: River Basins within Cambodia (defined by MOWRAM)

Table 2: Surface Area by River Basin

Basin Group	Code	River basin	Area (km²)	Basin Group	Code	River basin	Area (km²)
I	1	Prek Kampong Bay	3,018	III	30	Prek Preah	2,399
	2	Prek Toek Sap	1,529		31	Prek Krieng	3,331
	3	Prek Sre Ambel	2,653		32	Prek Kampi	1,142
	4	Prek Andong Toek	2,460		33	Prek Te	4,363
	5	Prek Trapang Rung	2,615		35A	Mekong Riverine (Downstream)	8,287
	6	Prek Tatai	1,619			**Sub-Total III**	**19,522**
	7	Prek Koh Pao	3,109	IV	12	Stung Krang Ponley	3,033
	8	Stung Me Toek	1,043		13	Stung Baribour	3,003
		Sub-Total I	**18,046**		14	Stung Bamnak	1,116
II	27	Tonle Se Kong	5,564		15	Stung Pursat	5,964
	28	Tonle Se San	8,021		16	Stung Svay Don Keo	2,228
	29	Tonle Srepok	12,380		17	Stung Moung Russei (Dauntry)	1,468
		Sub-Total II	**25,965**		18	Stung Sangker	6,052
V	9	Stung Toan Han	1,765		19	Stung Mongkol Borey	5,264
	10	Stung Slakou	2,485		20	Stung Sisophon	5,593
	11	Stung Prek Thnot	7,055		21	Stung Sreng	9,931
	34	Prek Chhlong	5,599		22	Stung Siem Reap	3,619
	35B	Mekong Riverine (Upstream)	2,086		23	Stung Chikreng	2,714
	37	Mekong Delta Cambodia	8,723		24	Stung Staung	4,357
	38	Mekong TS flood plain (Spean Troas)	1,508		25	Stung Sen	16,342
	36	Tonle Vaico	6,618		26	Stung Chinit	8,236
		Sub-Total V	**35,839**		39	Boeng Tonle Sap	2,743
						Sub-Total IV	**81,663**
TOTAL = 181,035 km²							

4. Methodology

43. This report, providing a preliminary flood and droughts risk assessment, is based on existing reports and studies. The methodology used was as followings:

a. Conduct a literature review to identify documents and maps related to flood and drought risk assessment.
b. Complete a review of identified reports and studies on the occurrence and severity of past floods and droughts.
c. Summarize the results and findings of the reports and studies reviewed.
d. Categorize the severity and occurrence of floods and droughts by basins using the results and findings of the reports and studies reviewed.
e. Identify basins where significant flood and droughts have occurred, the damage caused by the event, and the associate risk where possible.

44. The application of this methodology resulted in a list of basins that are susceptible to floods and drought events.

45. A brief introduction to flood and drought risk assessment and terminology is provided in the following sub-section for context and was used to guide the review of the studies and reports referenced and to standardize the presentation of results.

4.1. Flood Risk Assessment

46. Flood risk assessment refers to the quantitative analysis of the level of flood risk in an area or basin. 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. The level of risk is also related to the probability that a flood event of a specific magnitude will occur.

47. The process for conducting flood risk assessment is shown by **Figure 4**.

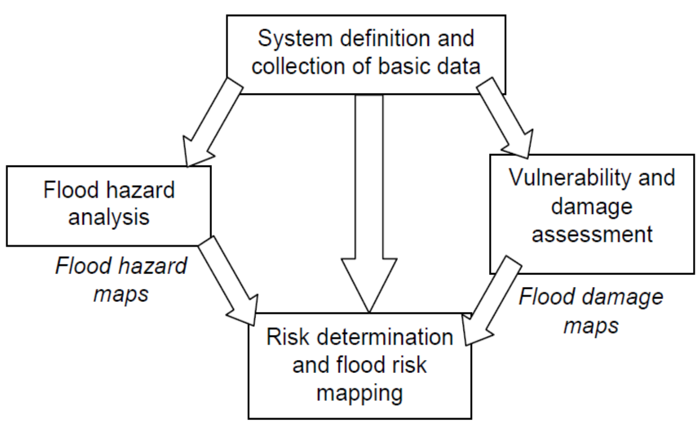


Figure 4: General scheme for flood risk assessment

48. System definition and collection of basic data: the first step is to define the hydrographic system and to collection relevant data for the study area such as the elevation of the terrain, the hydraulic processes, and past events.

49. Flood hazard analysis: the second step is to conduct an analysis of flood occurrence. It involves an analysis of 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 of the flood hazard. The flood hazard is defined in terms of inundation area, height of water, water velocity, and duration considering meteorological, hydrological, and the river channel and floodplain characteristics. The results are displayed by means of flood hazard map.

50. Vulnerability and damage assessment: the third step is the analysis of potential damages based on socio-economic data for the flood prone area and to build a vulnerability/damage model.

51. Risk determination and flood risk mapping: the final step involves the determination of risk by combining the results of the flood hazard analysis for an associated probability of occurrence 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 (frequency of occurrence).

4.2. Drought Risk Assessment

52. Drought risk assessment is generally more difficult to quantify and can vary depending on the type of drought. The types of droughts can be defined as:

- Meteorological droughts - defined by low rainfall over the wet season (May to November), which reduce the yield of rain-fed rice and other crops. Over 90 percent of rice production in Cambodia is rice-fed.
- Hydrological drought - defined by a reduction in the availability of surface and groundwater.
- Agricultural drought - considers the effect of the reduced availability of soil moisture on crop yields, whether for food or fodder.

53. 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.

54. The analysis is used to develop a number of drought descriptors for the drought hazard. These include:

- Duration - the period that the meteorological or hydrological drought was below a given threshold
- Severity - how intense the drought was
- Spatial coverage - area affected
- Intensity - ratio of severity to duration

5. Review of flood and drought risk assessment reports and studies

55. The review considered the following information:

- Reports and studies describing past floods and droughts.
- Reports and studies presenting future projections of flood and drought occurrences that consider climate projections.
- Maps showing river basins and sub-basins, geomorphologic characteristics such as floodplains and natural retention areas, the location of existing flood defence infrastructure, topography, land use, population areas, transportation routes, and cultural heritage sites,

56. The following sub-sections summarize the relevant reports and studies that were reviewed.

5.1. "Strengthening the Disaster Management Systems in Cambodia through Risk Assessment, Early Warning Systems and Developing Building Codes" (NCDM/ADPC, 2014)

57. The National Committee for Disaster Management in Cambodia (NCDM) in 2014 updated the Natural Hazard Risk Information database. The assessment and resulting information was developed using a standardized scientific approach at national and provincial levels.

58. The assessment was performed considering four major hazards: typhoons, droughts, floods, and epidemics. These hazards were selected in close consultation with stakeholders. The data on historical information for hydrometeorology and geomorphology were used to model and to identify the hazard extent. The spatial distribution of the hazard was determined for 10, 25, 50, and 100-year return periods. The flood hazard was assessed using the HEC-RAS model. Historical rainfall data for a 30-year period were used to assess the drought hazard. Standardized Precipitation Index (SPI) values were calculated.

59. Risk was estimated considering potential consequences of a hazard event and its likelihood of occurrence. The risk assessment was completed following the four steps of hazard assessment, exposure analysis, defining vulnerabilities, and the estimation of risk.

60. Flood risk maps for 10, 25, 50, and 100-year return periods were produced for the flood-inundated areas along the mainstream rivers - Mekong, Tonle Sap, and Bassac (**Figure 5**). Web based digital “Risk Atlas” comprising of risk maps and the report on “National and Provincial Risk Assessment, Cambodia – 2014” were compiled as the main means of sharing risk information.

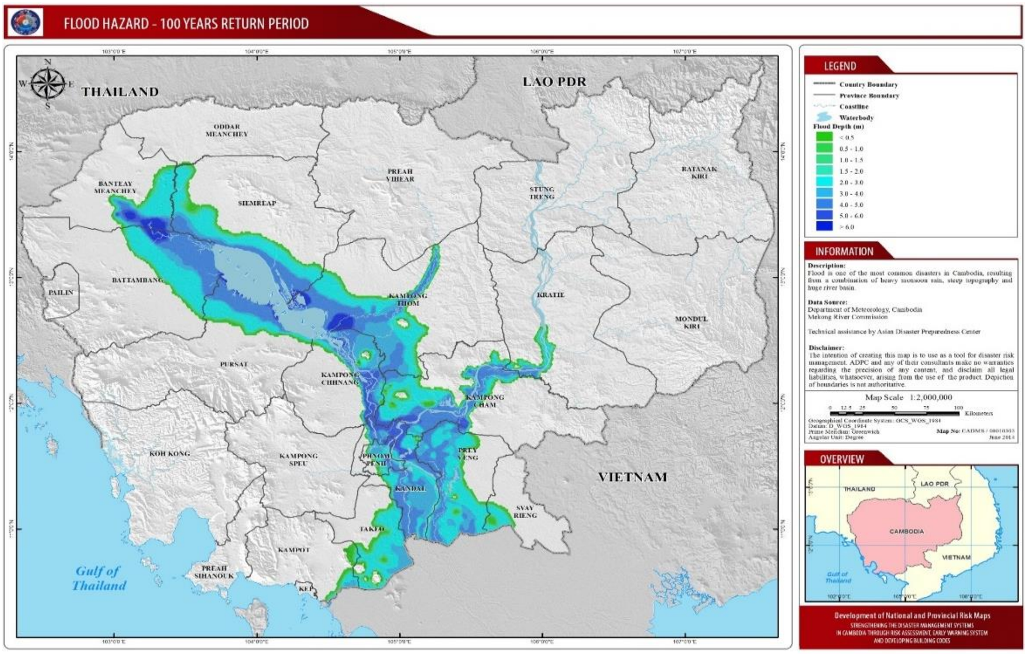
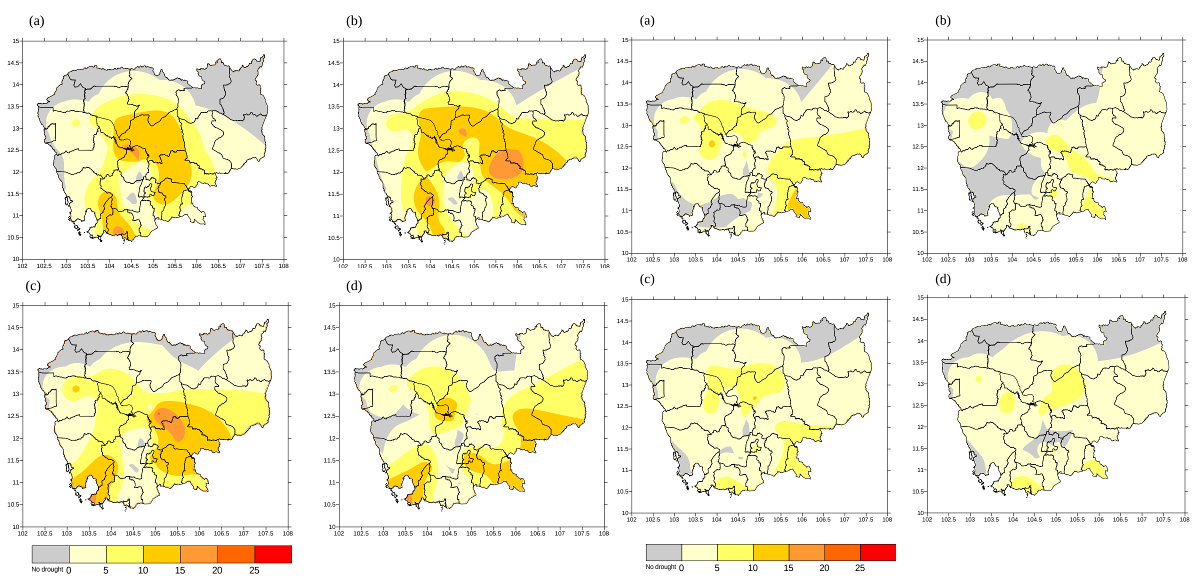
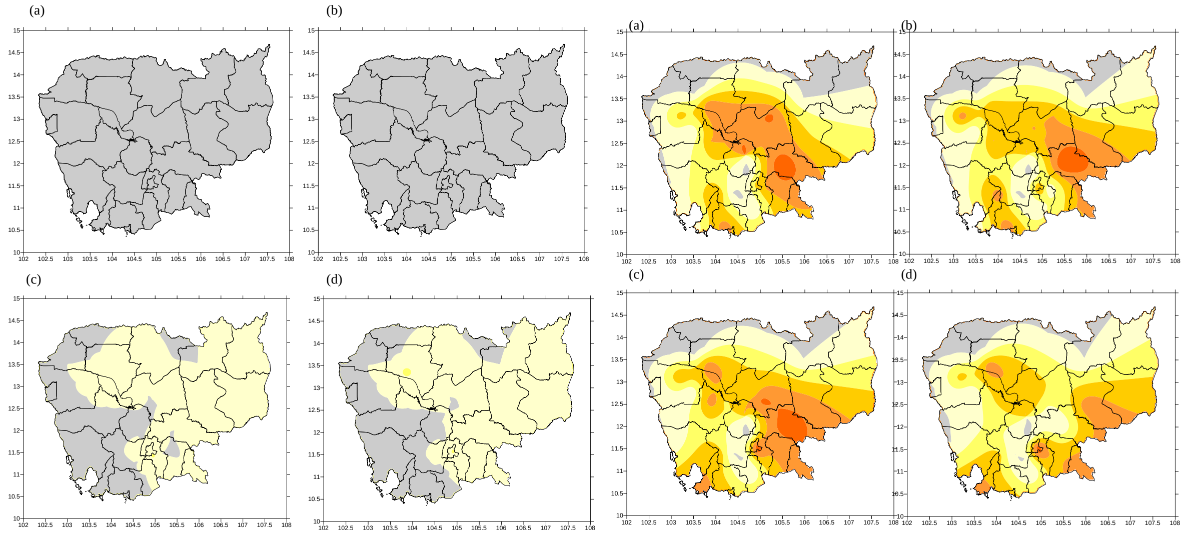


Figure 5: Flood hazard map for 100-year return period

61. Drought risk maps based on the probability of occurrence of droughts (A: moderate, B: severe, C: extreme and D: moderate to extreme) were produced. Based on the analysis of the probability of occurrence of drought at various stations, low drought susceptible and high drought susceptible areas were categorized as areas having 15 to 20 percent and greater than 20 percent probabilities, respectively. The results are shown by **Figure 6.**



A: Moderate B: Severe



C: Extreme D: Moderate to Extreme

Figure 6: Drought susceptibility maps for (a) dry season (hot) (b) dry season (cold) (c) rainy season and (d) March-February (annual).

5.2. MRC Working Paper 2011-2015: "The Impact and Management of Floods and Droughts in the Lower Mekong Basin and the Implication of possible Climate Change". (MRC, 2012)

62. This MRC working paper discussed the nature of floods and droughts in the Lower Mekong Basin (LMB) as well as measures for risk management.

63. Five primary and four supplementary measures were identified to manage flood risk.

64. The five primary measures are (i) land-use zoning (keep people away from the water), (ii) structural works (keep water away from the people), (iii) development and building controls (recognize that people will be flooded and the attempt is to limit damage to buildings and infrastructure through 'flood proofing' measures), (iv) regional flood emergency planning, and (v) community-based flood emergency planning.

65. The four supplementary measures are land-use planning, flood simulation modelling, flood forecasting, and flood warning.

66. These nine flood risk management measures interact in a complex way. Their utility and effectiveness must be considered when developing an 'integrated flood risk management plan'.

67. Three primary and three supplementary measures were identified to manage drought risk. The three primary measures are (i) structural works (supplementary water supplies or water conservation works), (ii) regional drought emergency planning, and (iii) community-based drought risk management. The three supplementary measures are drought monitoring, drought forecasting, and drought warning.

68. The utility and effectiveness of these six drought risk management measures must be considered when developing an 'integrated drought risk management plan'.

69. As well, the report examined and identified shortcomings in several studies on climate change in the LMB. Based on these shortcomings, the report presented an outline for mitigating and adapting to climate change in the basin.

5.3. Flood Damage Emergency Reconstruction Project: Preliminary Damage and Loss Assessment (ADB, 2012)

70. This report investigated and provided an assessment of damage using a post disaster needs analysis (PDNA) approach and a damage and loss analysis (DALA) approach.

71. For example, the assessment of the Cambodia 2011 Flood identified the following damages and losses:

- Fatalities affected: 250
- Provinces affected: 18 out of 24 (**Figure 7**)
- Households affected: 354,217 (More than 1.7 million people)
- Households evacuated: 51,950
- Infrastructure Damaged:
  - National /Provincial Roads – 363 km and 177 bridges /culverts damaged (overall 925 km affected)
  - Rural Roads – 1,842 km needing priority repairs (overall 4,470 km affected)
  - Irrigation – 329 schemes partly damaged (includes damage to 54 km of canals and 122 km of reservoir embankment)
  - Rural Water Supply – 77,544 wells and 579 community ponds contaminated (affecting more than 456,000 families)
  - 1,396 schools and 115 health centres
  - Rice fields damaged: around 10%, of which 6.6% fully destroyed

72. Main sectors affected:

- Transport - US$ 344.4 million or 57% of the total (89% damage, 11% loss).
- Agriculture - US$ 179.6 million or 29% of the total (22% damage, 88% loss).
- Irrigation and water management - US$ 27.1 million or 4.5% of total (this includes only damage as it was not possible to estimate the loss).
- Rural water and sanitation - US$ 31.4 million (64% damage, 36% loss), although the monetary impact is marginal, the present conditions of rural water and sanitation will lead to health hazards.
- Agriculture - 163,377 ha of paddy rice destroyed valued at a total of $178.8 million (US$ 40.8 million lost planting, US$ 138 million lost paddy production).
- Loss of wages in agriculture - US$ 7.3 million, a small but important loss.
- Exported milled rice – reduced by US$ 43.6 million compared to potential.

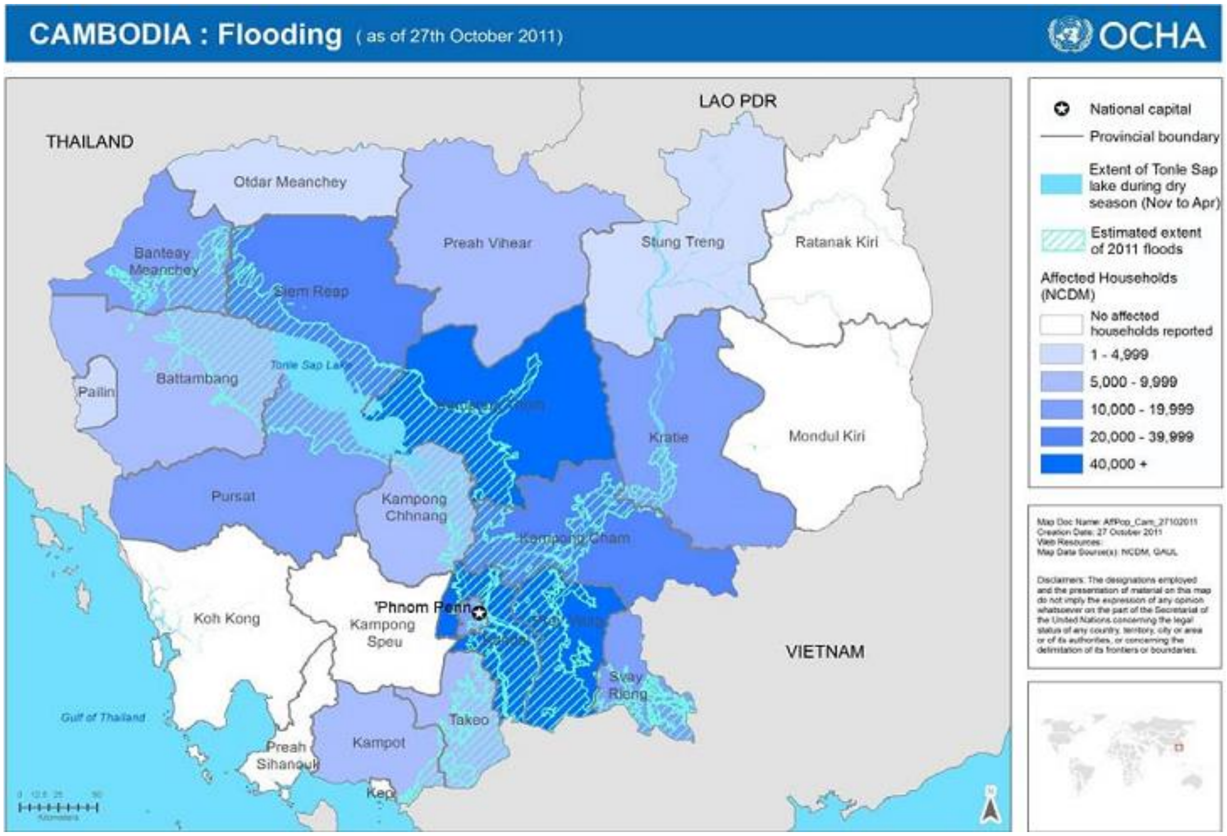


Figure 7: Impact of 2011 Flood - Cambodia

5.4. Summary of Risk Assessment in Cambodia (NCDM Report, 2011)

73. This report provided an assessment of the effects of flood and droughts in 2011.

Flood:

- Recent Mekong extreme floods affected Cambodia in 1978, 1991, 1996, 2000, 2001, 2002, and 2011. The 2000 Mekong flooding in Cambodia was reportedly the worst in more than 70 years. The official report compiled by the National Committee for Disaster Management (NCDM) on 16 November 2000, put the death toll at 347 (80 % of whom were children). Of the 750,618 families (3,448,629 individuals) affected by flooding, about 85,000 families (387,000 individuals) were temporarily evacuated.
- Based on official statistics issued by NCDM on 3 Nov 2011: the 2011 flood struck many parts of 18 cities and provinces (Kampong Thom, Battambang, Banteay Meanchey, and Siem Reap were the most affected). The death toll was 250; 1,593,976 persons or 354,217 families were affected and more than 23,000 families were evacuated to higher ground. The magnitude of the 2011 flood was less than in 2000 but the 2011 flood caused more damage than the 2000 flood.
- Extreme flash floods occurred in 2007 (caused by tropical storm "PABUK" in earlier August), 2009 (caused by the tropical storm "Ketsana" at the end of September), 2010 (caused by a tropical depression during 10-12 October), and in 2011 flash floods occurred twice in Siem Reap due to tropical depressions.

Typhoon:

- In 2009, Typhoon Ketsana struck Cambodia and affected 14 of Cambodia's 24 provinces. While the efforts for the recovery from Typhoon Ketsana were still ongoing, prolonged rain as a result of the rainy season (September to October) caused significant flooding to areas that were already affected by Typhoon Ketsana.

Drought:

- In 2011, drought affected 3,804 hectares and destroyed 53 hectares of rice fields.

5.5. MRC "Structural Measures and Flood Proofing", (2010)

74. Under Component 2 of the MRC's FMMP (FMMP-C2): "Structural Measures and Flood Proofing" in 2010, Best Practice Guidelines for flood risk assessment were developed to provide policy-makers, managers, and FMM professionals in MRC as well as in national line agencies with a common knowledge base for considering flood risk assessment during policy formulation, strategy and plan development, and project design and evaluation for flood risk management in the Lower Mekong Basin.

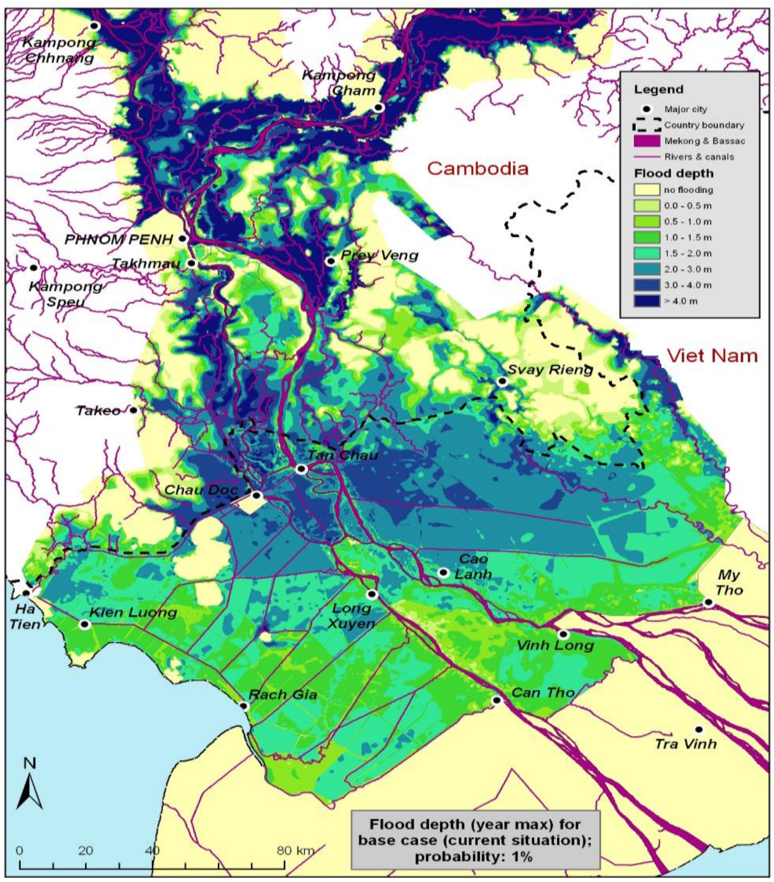


Figure 8: 100-year flood map for the Mekong Delta

75. FMMP-C2 developed flood vulnerability indices for the Lower Mekong basin, and produced flood risk maps for 2, 5, 10, 20, 50, and 100-year return periods for flood-prone provinces in Cambodia and Vietnam (**Figure 8**).

5.6. Cambodia: Post Ketsana disaster needs assessment, 2010

76. Under the Leadership of the Cambodian National Committee for Disaster Management the Royal Government of Cambodia conducted a post Ketsana damage assessment with support from the World Bank, GFDRR, UN System, ADB, and ADPC.

77. Typhoon Ketsana struck Cambodia between September 29 and October 5, 2009. Some 14 of 24 provinces (**Figure 9**) were affected by the storm and subsequent flash floods. The typhoon left 43 people dead, 67 people severely injured, and destroyed homes and livelihoods of some 49,000 families, or about 180,000 people, which is equivalent to 1.4 percent of Cambodia's total population. Many of the affected districts were among the poorest in the country. The widespread damage to property, livelihoods, and public infrastructure in these areas had a long-term impact.

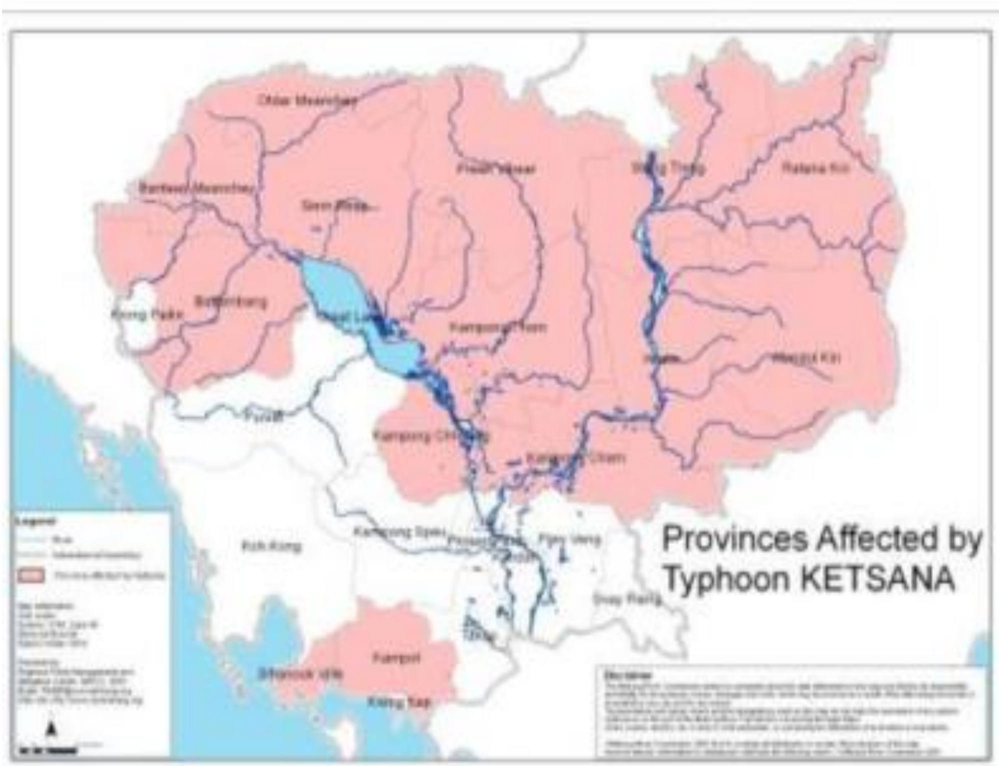


Figure 9: Cambodian Provinces affected by Typhoon Ketsana

5.7. Mapping Vulnerability to Natural Disasters in Cambodia (National Committee for Disaster Management, Royal Government of Cambodia United Nations World Food Program, 2003)

78. This report presents the main findings of a study to identify priority areas at the commune level in Cambodia prone to floods and droughts. It identified various factors contributing to vulnerability of rural populations as a result of natural disasters. In particular, the analysis focused on three elements: food security, rice dependency, and the nature of the disaster. The combination of existing information and data from surveys, assessments, geographic information systems (GIS), and satellite images enabled the researchers to identify the communes that are prone to natural disasters.

5.8. Impact of Disasters and Role of Social Protection in Natural Disaster Risk Management in Cambodia (Economic Research Institute for ASIAN and East Asia-ERI-DP-2013)

79. This report presents the impact of disasters on household welfare and linked the effectiveness of social protection interventions for poor and vulnerable people suffering from floods and droughts. The analysis classified and identified a number of cluster areas impacted by floods and droughts in Cambodia.

80. The specific aims of this report were:

- to conduct ex-post and ex-ante analysis of the past and potential socioeconomic impacts of disasters on the livelihoods of the rural poor in Cambodia,
- to assess risk-coping strategies of households, and
- to highlight disaster management system, focusing on the role of social protection.

81. The report utilized socioeconomic survey data from 2004 and 2009 and conducted a unique questionnaire survey in 2012 to support the empirical analyses. **Figure 10** shows the 5 cluster areas, which where based on an agro-ecological typology.

82. The description for each of the clusters is as follows:

- **Cluster 1**: Areas with inundated plains, prone to secondary river flooding and prolonged drought.
- **Cluster 2**: Areas with undulated plains, prone to flooding from Great Lake during the rainy season (Tonle Sap) but reliant on the delayed recession of floodwater during the dry season.
- **Cluster 3**: Areas of riverbank, prone to Upper Mekong flooding during the rainy season but reliant on the fast recession of floodwater during the dry season.
- **Cluster 4**: Areas with extreme undulated plains, prone to Lower Mekong flooding and vulnerable to the speed of flooding and prolonged drought
- **Cluster 5**: Areas of riverbank with secondary swamp lakes, prone to Lower Mekong flooding during the rainy season but reliant on the fast recession of floodwater during the dry season

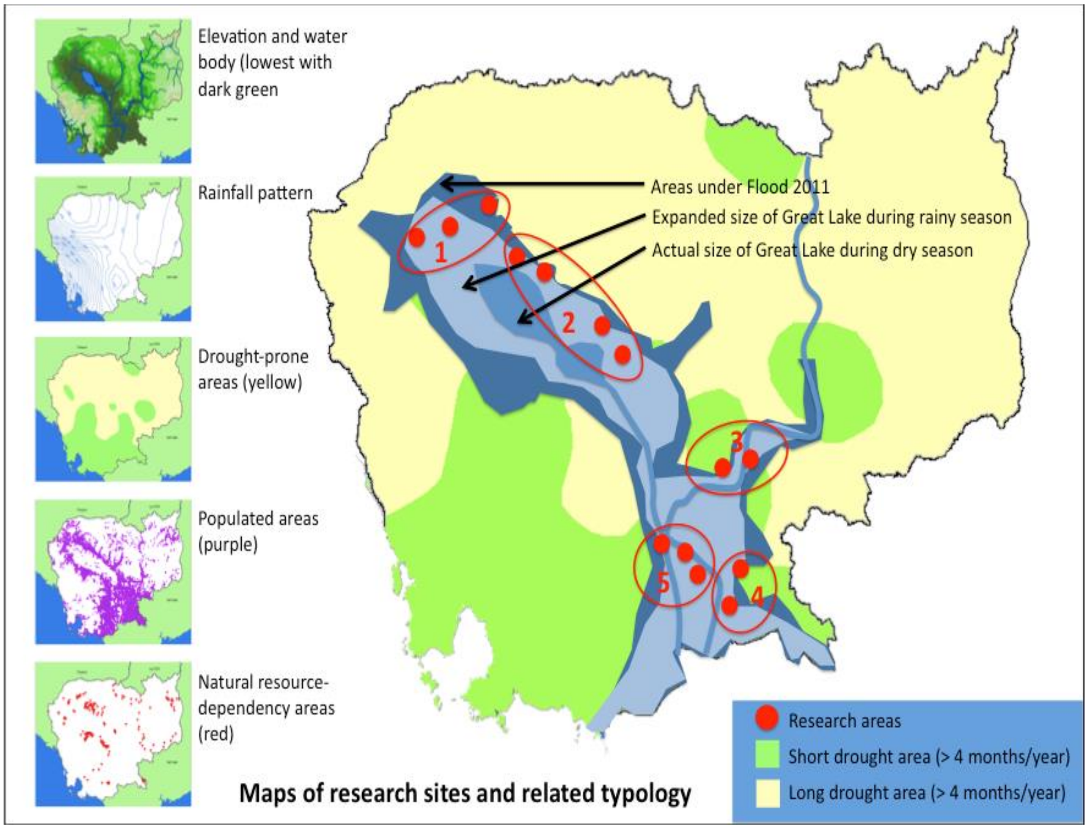


Figure 10: Map showing Research Sites and 5 Clusters Area impacted by Floods and Droughts

83. The results of the study for years 2004, 2009, and 2012, which experienced floods and droughts events, as well as the degree of severity for each agro-ecological cluster are presented in **Table 3**. The table shows the total months experiencing floods and droughts for the three years studied and the total level of severity. A comparison to the severity of the 2011 flood is also shown.

Table 3: Flood and Drought Severity by Agro-ecological Cluster - Cambodia

Areas	Total number of Months		Total Level of Severity		Flood 2011
	Flood	Drought	Flood	Drought	Severity
1	4.51	8.32	14.84	13.14	6.89
2	5.95	6.04	14.36	12.63	7.37
3	5.89	4.13	13.87	12.28	9.43
4	6.05	9.49	14.24	10.66	8.98
5	4.97	5.32	13.53	10.97	7.08
Total	**5.47**	**6.66**	**14.17**	**11.94**	**7.95**

5.9. Greater Mekong Sub-region Flood and Drought Risk Management and Mitigation Project, Final Main Report - Cambodia (ADB TA 6456-REG)

84. This report noted that flood and drought risks are the main obstacle to poverty reduction and economic development in Cambodia. While the people of Cambodia have adapted to the annual floods and are used to “living with floods”, they are less prepared for droughts, which occur with a frequency of once in every three years.

85. Meteorological droughts, due to low rainfall over the wet season (May- November), reduce yields of rain-fed rice and other crops. As well, hydrological droughts affect agriculture in the dry season due to less than normal stream flows, which reduce irrigation water supply and adversely affect dry season production.

86. The study focused on floods in Cambodia for years, 1961, 1966, 1996, 2000, 2001, 2004, and 2006, and on severe droughts during the year 2001 to 2003. **Figure 11** presents the flood and drought prone areas in Cambodia, based on the years studied in report. **Table 4** presents information on losses and damage due to flood and drought events in Cambodia for the period 1987 to 2007. The information presented is based on a national data set on losses and damages due to floods and droughts as recorded by the National Committee for Disaster Management (NCDM).

Flood **Drought**

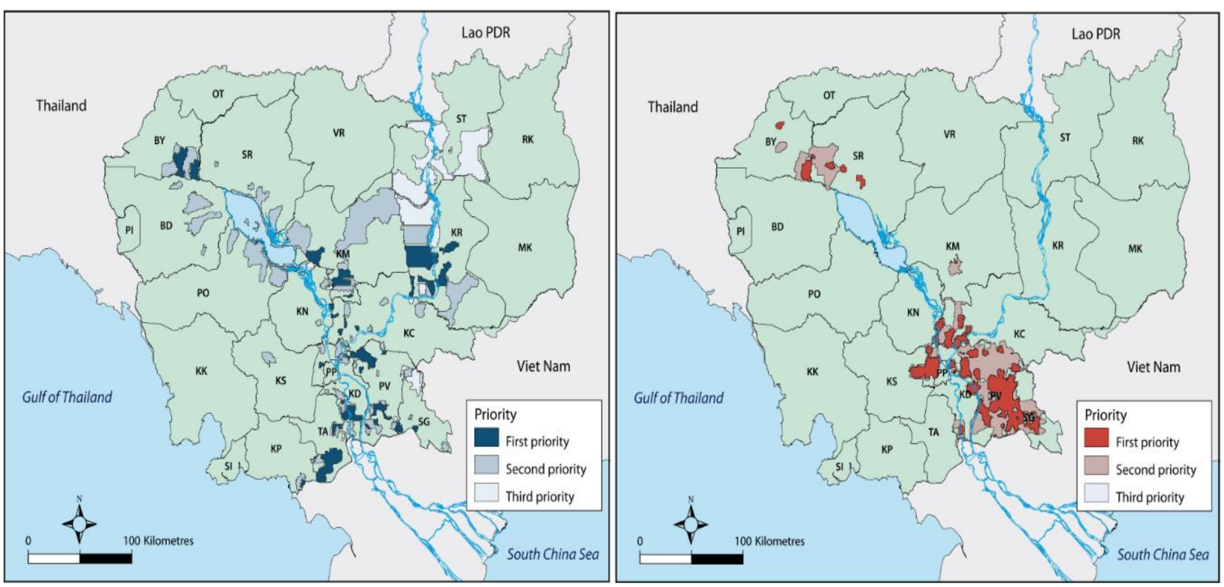


Figure 11: Flood and Drought Prone Communes in Cambodia

Source: www.foodsecurityatlas.org/khm/country/vulnerability/risk-analysis

Table 4. Flood and Drought Related Losses and Damages in Cambodia (1987-2007)

Calamities	No. of Event	Killed	Injured	Homeless	Population Affected	Damage US$ (in 000's)
Flood	12	1,125	53	275,805	9,524,614	327,100
Drought	5	0	0	0	6,550,000	138,000

5.10. Country Report of Cambodia on Disaster Management (Leng Heng An, NCDM-2014)

87. This report highlights the impact of flood events during 2000 to 2013 and drought events in 2009, 2010, 2011, and 2012.

Flood (2000-2013):

88. The flood in 2011 affected 350,000 households (over 1.5 million people) with 52,000 households being evacuated. The 2011 floods caused an estimated loss at US$ 630 million.

89. The flood in 2013 affected 20 of 24 provinces, 377,354 households, claimed 168 lives, and forced 31,314 households to evacuate to safe areas.

90. The number of affected provinces by flood year is shown in **Figure 12**.

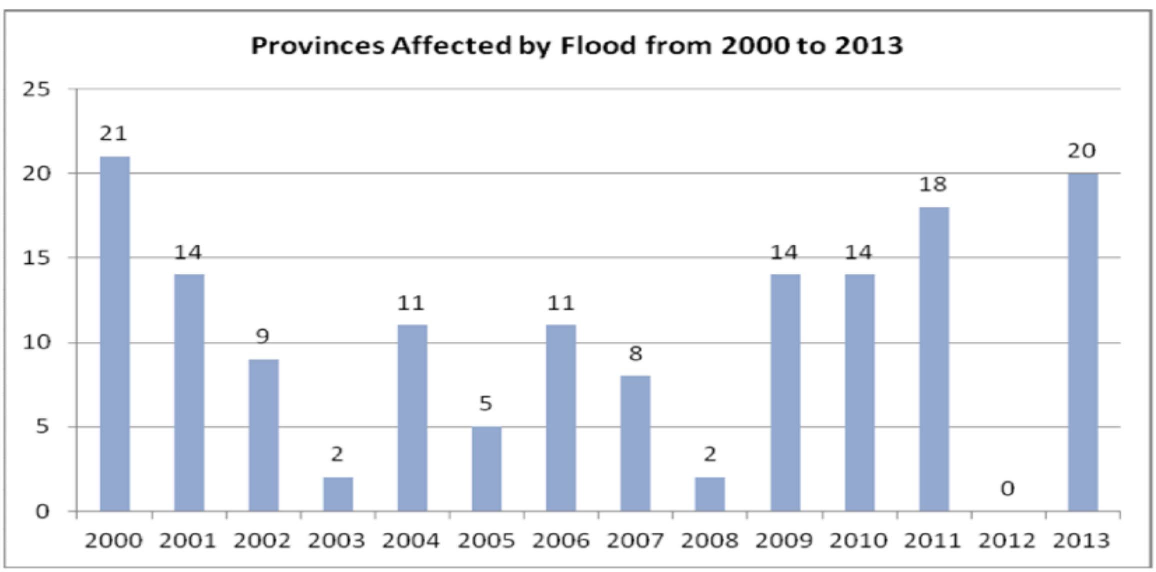


Figure 12: Number of Provinces affected by floods - Cambodia

Drought (2000-2012):

91. The drought in 2009 affected 13 of 24 provinces and caused damage to 2,621 ha of rice crops.

92. The drought in 2010 affected 12 of 24 provinces and caused damage to 5,415 ha of subsidiary crops.

93. The drought in 2011 affected 12 of 24 provinces and caused damage to 5,415 ha of subsidiary crops.

94. The 2012 drought affected 12 of 24 provinces and caused damage to 3,151 ha of rice.

95. The number of affected provinces by drought year is shown in **Figure 13.**

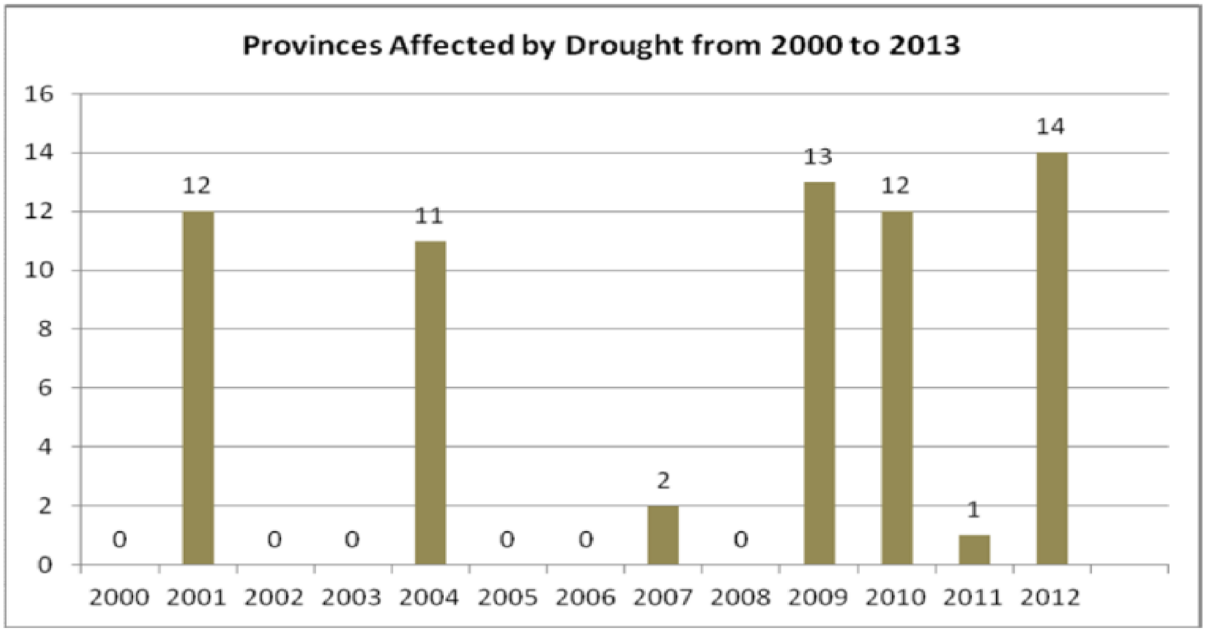


Figure 13**:** Number of Provinces affected by Drought - Cambodia

5.11. Adaptation to climate change in the countries of the Lower Mekong Basin: Regional Synthesis Report (MRC, Technical paper No. 4, 2009)

96. This report focuses on climate change in the Lower Mekong Basin (LMB). The report provides information on regional and national adaptation activities as well as identifies policy and institutional responses. Based on a “gap analysis” the report presents a series of recommendations for future climate change related actions in the Mekong region. The report highlights the communes most at risk to floods and droughts in Cambodia and is based on the data from WFP 2005 and **Figure 11**, previously shown.

97. The report noted that Cambodia experiences yearly floods and droughts, but preparedness and adaptive capacity in the country is very low. The analysis showed that changes in soil water availability, caused by the combined effects of temperature and rainfall changes, could have a significant impact on forest composition and biomass production.

98. The report concluded that Cambodia's area of wet and dry forests would decrease while the area of moist forest would increase under projected climate change scenarios. This change in land cover would have significant impacts on watershed protection, agricultural production, and hydroelectricity output.

99. The report recommended that the mainstreaming of climate change adaptation into development actions should not be considered by a stand-alone sector. As a consequence, the report proposed that climate change adaption must be considered a crosscutting issue requiring a broad sector approach. As well, the report recommended that technical training seminars are required and must be geared towards government agency staff involved in agriculture, education, rural development, planning, public works and transport, water resources and meteorology as well staff of development NGOs operating in water related activities.

5.12. Impact of climate change and development on Mekong flow regimes. First assessment – 2009 (MRC, Technical paper No. 29, 2010)

100. This report presents the results of an assessment of the impacts of climate change as well as the impact of hydropower and irrigation developments on the river flow regime in the Lower Mekong Basin. The report presents:

- A framework for climate change analysis and its application to the MRC Basin Development Plan (BDP) Scenarios,
- Results from the Decision Support Framework (DSF) model for the analysis of climate change impacts considering selected BDP Scenarios on flow regimes; and
- Recommendations for further studies to identify adaptation strategies for mitigating impacts.

101. Two BDP Scenarios, namely the Baseline Scenario and the LMB 20-Year Plan Scenario hereafter called the Development Scenario, were selected to compare the impacts of climate change on the flow regime.

102. The climate change projection used the climate daily data (2010-2050) of Scenarios A2 and B2 from the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios (IPCC SRES) based on ECHAM4 GCM.

103. Six scenarios were defined of which three considered no climate change (Scenarios 1 and 2 were Baseline and Scenario 3 was a Development Scenario).

104. The other three scenarios took into account climate change and development. Scenario 4 considered only climate change, Scenario 5 considered Scenario 4 plus the Development Scenario, and Scenario 6 considered Scenario 5 with adaptation.

105. The DSF simulation model, the SWAT hydrological model, the IQQM basin simulation model, and the hydrodynamic ISIS model were used to develop the flow changes under different climate and

development options. Flow impacts were identified for the stations on the mainstream Mekong considering a 20-year development horizon.

Table 5, 6, and **7** and **Figure 14** show the expected change in flows for the mainstream stations and in flood depth in the Mekong delta from combinations of climate change and development.

Table 5: Flow change resulting from climate change in the Baseline Scenario

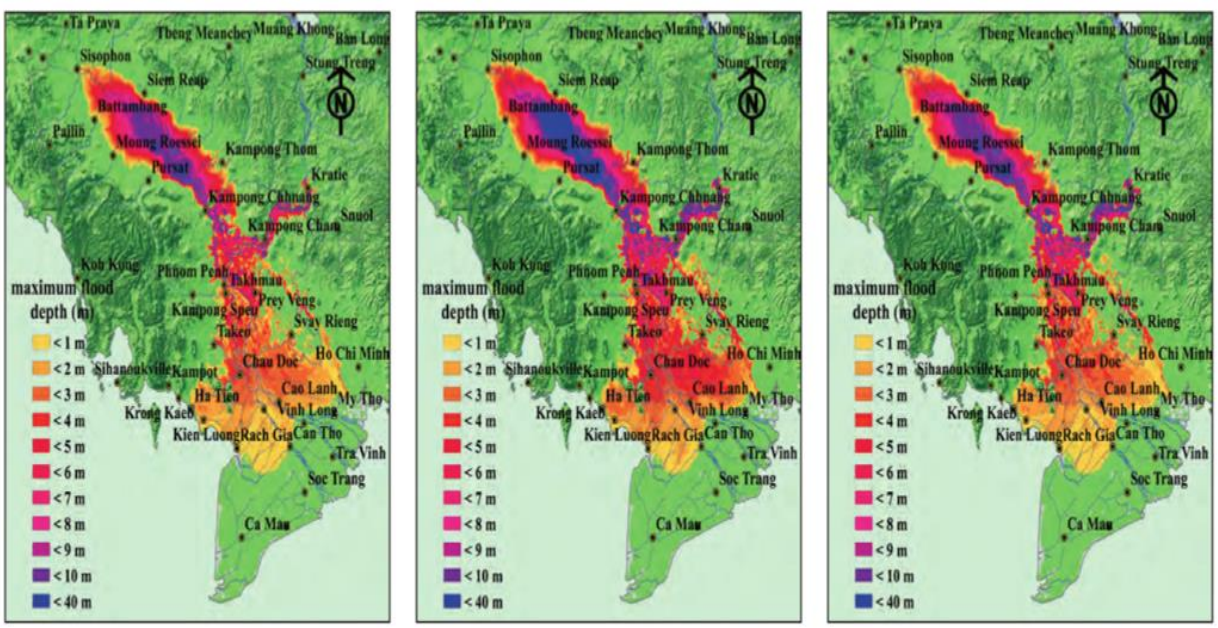
Station	Flow Change (+/- m^3/s)						Flow Change (+/- %)					
	A2			B2			A2			B2		
	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050
	High-flow season	Low-flow season	Annual	High-flow season	Low-flow season	Annual	High-flow season	Low-flow season	Annual	High-flow season	Low-flow season	Annual
Scenario	S4-S2	S4-S2	S4-S2	S4-S2	S4-S2	S4-S2	S4-S2	S4-S2	S4-S2	S4-S2	S4-S2	S4-S2
Stung Treng	2,318	810	1,564	1,048	682	865	11.1	23.0	12.8	5.0	19.4	7.1
Kratie	2,341	798	1,569	1,060	679	870	11.2	22.7	12.9	5.1	19.3	7.1
Kompong Cham	2,094	774	1,434	942	650	796	10.0	21.2	11.7	4.5	17.8	6.5
Phnom Penh	1,495	775	1,135	570	642	606	7.4	20.8	9.5	2.8	17.3	5.1

Table 6: Flow change resulting from development and climate change in the Baseline Scenario

Station	Flow Change (+/- m^3/s)						Flow Change (+/- %)					
	A2			B2			A2			B2		
	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050	2010-2050
	High-flow season	Low-flow season	Annual	High-flow season	Low-flow season	Annual	High-flow season	Low-flow season	Annual	High-flow season	Low-flow season	Annual
Scenario	S5-S2	S5-S2	S5-S2	S5-S2	S5-S2	S5-S2	S5-S2	S5-S2	S5-S2	S5-S2	S5-S2	S5-S2
Stung Treng	674	1,586	1,130	-601	1,518	458	3.2	45.1	9.3	-2.9	43.2	3.8
Kratie	681	1,582	1,132	-609	1,528	459	3.2	43.7	9.0	-2.8	42.2	3.6
Kompong Cham	588	1,558	1,073	-572	1,493	460	2.8	42.7	8.7	-2.7	40.9	3.7
Phnom Penh	278	1,561	920	-674	1,480	403	1.4	42.0	7.7	-3.3	39.8	3.4

Table 7: Flooded areas under different development and climate change scenarios

Maximum Flood Depth (m)	Flood Area based on Maximum Flood Depth (km²)						Difference in Flooded Area (+/- km²)					Difference in Flooded Area (+/- %)				
	Baseline 2000	Baseline 2048 A2	Baseline 2047 B2	Dev 2000	Dev 2048 A2	Dev 2047 B2	Baseline 2048 A2	Baseline 2047 B2	Dev 2000	Dev 2048 A2	Dev 2047 B2	Baseline 2048 A2	Baseline 2047 B2	Dev 2000	Dev 2048 A2	Dev 2047 B2
	S2	S4	S4	S3	S5	S5	S4-S2	S4-S2	S3-S2	S5-S2	S5-S2	S4-S2	S4-S2	S3-S2	S5-S2	S5-S2
Peak daily discharge at Kratie (m^3/s)	*54,922**	*95,293*	*90,117*	*50,807*	*92,922*	*92,569*	*40,370*	*35,195*	*-4,116*	*38,000*	*37,647*	*73.5*	*64.1*	*-7.5*	*69.2*	*68.5*
> 0.0 m	44,654	48,579	46,037	43,121	48,295	45,753	3,925	1,383	-1,533	3,642	1,099	8.8	3.1	-3.4	8.2	2.5
> 0.5 m	41,317	46,915	42,657	39,541	46,599	42,253	5,598	1,340	-1,776	5,282	936	13.5	3.2	-4.3	12.8	2.3
> 1.0 m	36,393	43,917	38,311	33,352	43,457	37,620	7,524	1,918	-3,041	7,065	1,227	20.7	5.3	-8.4	19.4	3.4
> 1.5 m	30,923	40,563	33,061	27,946	40,003	32,355	9,641	2,138	-2,976	9,081	1,432	31.2	6.9	-9.6	29.4	4.6
> 2.0 m	26,347	36,459	28,993	22,975	35,703	28,334	10,112	2,645	-3,372	9,356	1,987	38.4	10.0	-12.8	35.5	7.5
> 2.5 m	21,971	32,783	24,924	19,060	31,951	24,212	10,812	2,953	-2,912	9,980	2,241	49.2	13.4	-13.3	45.4	10.2
> 3.0 m	17,977	29,006	20,934	15,767	28,211	20,275	11,028	2,957	-2,210	10,234	2,298	61.3	16.4	-12.3	56.9	12.8
> 3.5 m	15,198	25,501	17,439	13,897	24,588	17,136	10,302	2,241	-1,301	9,390	1,938	67.8	14.7	-8.6	61.8	12.7
> 4.0 m	13,570	21,422	15,656	12,152	20,424	15,433	7,852	2,086	-1,418	6,854	1,863	57.9	15.4	-10.5	50.5	13.7



Flooded areas in 2000 under Scenario S2 (left), in 2048 under Scenario S5 A2 (middle) and under Scenario S5 B2 (right)

Figure 14: Change in flood area and depth considering climate change and development - LMB

106. In general, the study concluded that climate change would result in higher discharges in the high and low-flow seasons at all stations. The development of hydropower dams as considered in the Development Scenario will result in a lower discharge in the high-flow season. However, the discharge will be higher than that shown for the Baseline without climate change (1985 - 2000) and with climate change (2010 - 2050).

6. Identification of risk areas considering the analysis of historical data and previous studies

6.1. Floods

107. The reports reviewed in Chapter 5 present limited information on flood hazards and risks for the tributary basins as the studies were focused on the Mekong mainstream system and its associated flood prone areas.

108. Given this, the national team used its local knowledge and experience to identify provinces and tributary basins subject to notable flood hazards and risk. The team identified the following provinces, which have experienced floods with respect to flash floods:

- Kampong Thom,
- Pursat,
- Siem Reap,
- Battambang,
- Banteay Meanchey,
- Kampong Speu
- Stung Treng,
- Ratanak Kiri,

109. As well, the team identified river basins that have experienced notable flood events. The river basins are:

- Stung Sen
- Stung Pursat,
- Stung Siem Reap,
- Stung Sangker
- Stung Sisophon (transboundary)
- Stung Prek Thnot
- 3S Rivers: Tonle Sre Pok, Se San, and Se Kong

6.2. Droughts

110. Predominate areas subject to droughts were well described through the background in Chapter 2 and the review in Chapter 5. Consequently, the maps produced by NCDM/ADPC in 2014 have been used to identify notable drought risk areas.

111. NCDM categorized the severity and intensity of droughts in Cambodia into the three categories of moderate, severe, and extreme. The categorization considered the susceptibility of a moderate, severe, and extreme drought occurring during the dry season (hot), the dry season (cold), the monsoon season, and annual for the March to February period.

Tables 8 to 10 shows the Susceptible Areas identified by the NCDM for each category of moderate, severe, and extreme drought hazard.

Table 8: Moderate Drought Susceptible Areas

Season	Low susceptibility	High susceptibility
Dry season (hot)	Mondul Kiri, Stung Treng, Battambang, Pailin, most parts of Pursat, Koh Kong, Takeo, eastern parts of Kratie, northern parts of Phreah Vihear, Siem Reap, and some parts of Kampong Speu, Kampong Cham, Kandal, Phnom Penh	None
Dry season (cold)	Ratanak Kiri, Stung Treng, Pailin, Banteay Meanchey, Takeo, most parts of Stung Treng, Kandal, northern part of Preah Vihear, Siem Reap, and some parts of Pursat, Kong Kong, Kampong Speu, Kampong Chhnang	None
Monsoon Season	Northern part of the country, Pailin, Takeo, most parts of Battambang, Pursat, Kampot, Kampong Speu, Kampong Chhnang, some parts of Koh Kong, northern Kandal	Kampong Thom and its surrounding area
March-February (Annual)	Entire country except Sihanoukville, south-eastern part of the country, some part of Koh Kong and surrounding of Prey Prous and Kampong Thom	None

Source: NCDM, National and Provincial Risk Assessment 2014

Table 9: Severe Drought Susceptible Areas

Season	Low susceptibility	High susceptibility
Dry season (hot)	Whole country except most parts of Svay Rieng province	None
Dry season (cold)	Eastern and Southern parts of the country and Battambang and its surrounding area	None
Monsoon Season	Entire county	None
March-February (Annual)	Entire county	None

Source: NCDM, National and Provincial Risk Assessment 2014

Table 10: Extreme Drought Susceptible Areas

Season	Low susceptibility	High susceptibility
Dry season (hot)	None	None
Dry season (cold)	None	None
Monsoon Season	Whole country except western parts of the country	None
March-February (Annual)	Whole country except western parts of the country	None

Source: NCDM, National and Provincial Risk Assessment 2014

112. Considering the information shown in **Tables 8** to **10** and **Figures 2, 3,** and **5**, drought susceptible basins can be identified as shown in **Table 11**.

Table 11: Drought Susceptible Areas

Moderate Drought	Severe Drought	Extreme Drought
Prek Chhlong		Prek Chhlong
		3S rivers Tonle Ser Pok, Se San and se Kong
		4P rivers: Prek Preah, Prek Kampi, Prek Te and Prek Krieng
Stung Sen	Stung Sen	Stung Sen
Stung Staung,	Stung Staung,	Stung Staung,
Stung Chikreng	Stung Chikreng	Stung Chikreng
Stung Siem Reap	Stung Siem Reap	Stung Siem Reap
Stung Pursat	Stung Pursat	Stung Pursat
Stung Prek Thnot		Stung Prek Thnot
Some rivers in the Coastal zone		Some rivers in the Coastal zone
Mekong riverine and flood plain		Mekong riverine and flood plain

7. Climate change considerations

113. There is scientific consensus that climate change will alter weather patterns and the hydrologic cycle. However, despite continuing advances in climate change science there remains uncertainty about climate change impacts and outcomes.

114. Following the precautionary principle, one can assume that climate change will present development challenges for water resources management in Cambodia due to increased variability in the extremes and the frequency of floods and droughts.

115. Given these changes in flood and drought severity and occurrence, action must be taken to build climate change resilience policies and strategies. These policies and strategies must be adaptive in nature and ensure long-term sustainability.

116. Based on the MRC 2010 report discussed under section 5.12 above, climate change will result in higher discharges in the high and low-flow seasons at all Mekong mainstream stations.

8. Selection of significant flood and drought risk areas

117. Based on the information presented throughout this report, using considered factors: the availability of data and information, the severity of the event, the frequency of the event, population, economic importance, size of existing and planned investment and agricultural significant areas, the river basins that are most vulnerable to floods and drought are identified to be:

i. The Tonle Sap Great Lake basin:
    a. Stung Sen, Stung Siem Reap, Stung Sisophon, Stung Sangker, and Stung Pursat
ii. The 3S basin:
    a. Tonle Sre Pok, Se San, and Se Kong.
iii. Prek Thnot.
iv. Mekong riverine and flood plain.

8.1. Tonle Sap Great Lake Basin

8.1.1. Stung Sen Basin

118. Stung Sen basin is located in the north-eastern part of the Tonle Sap Great Lake with a drainage area of about 16,465 km² (Number 25 in **Figure 3**). The Stung Sen river originates from the highest elevation of approximately EL 790 m amsl in the upper western part of the basin at the Dangrek Mountain Range. The river flows in the south and south-eastern direction for about half of its length before turning towards the south and south-south-western direction. The Stung Sen river drains into the Tonle Sap Great Lake at a location opposite to Chnok Trou.

119. The total length of the Stung Sen river is about 508 km. Along its course, the river flows generally across a mild slope valley before reaching its extensive flood plain near the district town of Sandan. From this point downstream, the Stung Sen River meanders within a large flood plain of about 5 to 6 km wide consisting of many remnants of old river channels. This lower reach is subject to frequent flooding. In general, the ground elevation around the Provincial capital of Kampong Thom, where the gauging station is located, is about EL 10 m amsl.

8.1.2. Stung Siem Reap Basin

120. The Stung Siem Reap basin is a combination of two river sub-basins, namely, the Stung Siem Reap itself and the Stung Roluos. The Stung Siem Reap river has its source in the Koulen and Kbal Spean mountains at an elevation of 482 m amsl (Number 22 in **Figure 3**).

121. The upper basin flows in a northeast direction then turns south passing a number of Angkor historical temples before reaching the town of Siem Reap. The river length to the town of Siem Reap is 60 km and flows further for another 15 km before discharging into the Tonle Sap Great Lake at Chong Khneas.

122. The Stung Roluos river drains the eastern part of the basin and discharges water directly into the Great Lake.

123. At the Angkor Temple complex, flow from both rivers is diverted to supply water to Angkor city and to the Baray reservoirs. The flow of the Stung Roluos is also stored in the Taniev Reservoir near Phnom Bauk and partly diverted to East Baray and Sras Srang.

124. The total basin area of the Stung Siem Reap basin is 3,619 km². About 60% of the basin area has an elevation from 2 to 30 m amsl. The highest elevation in the basin is 482 m amsl.

125. The gauging station for the Stung Siem Reap river is located at the Prasat Keo (Angkor Thom). The Stung Roluos river is ungauged.

126. Floods frequently inundate the town of Siem Reap.

8.1.3. Stung Sisophon Basin

127. Stung Sisophon basin (Number 20 in **Figure 3**) is a combination of 3 rivers, the Stung Sisophon itself, the Stung Svay Chek, and the Stung Kampong Krasaing (Sre Memay).

128. The Stung Svay Chek river (ungauged) flows in a north to south direction from the Thai-Cambodian border for some 50 km before discharging into Stung Sisophon River.

129. The Stung Sisophon River flows in a west to east direction from the Thai-Cambodian border for some 60 km before reaching Sisophon Town, the Banteay Meanchey Municipality Town, and joins the Stung Mongkol Borey river at about 20 km downstream of Mongkol Borey.

130. The Stung Mongkol Borey river turns its course in a south-eastern direction and joins the Stung Sangker river at Bac Prea Village, located about 70 km downstream of the Mongkol Borey Town.

131. The Stung Kampong Krasaing (un-gauged) originates in the Dangrek mountains range, flows in a north then a southeast direction for a distance about 110 km before discharging water into the Stung Mongkol Borey some 30 km upstream of Bac Prea Village.

132. The total basin area of the Stung Sisophon basin in Cambodia is 5,593 km². A gauge station is located in the Sisophon Town.

133. In recent years floods frequently inundate the Poipot and Sisophon Towns due to the large rainfall events.

8.1.4. Stung Sangker Basin

134. Stung Sangker river (Number 18 in **Figure 3**) originates from the Elephant and Cardamom mountains at an elevation of 1,391 m amsl. The river flows from a southwest to north direction passing the Battambang Town and joins the Stung Mongkol Borey river at Bac Prea village about 40 km downstream from Battambang Town and then the Stung Sreng river another 10 km downstream before flowing into the Tonle Sap Great Lake.

135. The upper Stung Sangker river is the combination of two rivers, namely, the Stung Sangker itself and the Stung Chamlang Kuoy. At O Dambang, located some 5 km upstream Battambang Town, the river splits into two rivers, the Sangker itself and the Stung Chas river, then flows directly into the Tonle Sap Great Lake.

136. The Stung Sangker river basin has a total area of 6,052 km². More than one third of the basin area has an elevation of 4 to 13 m amsl, which is vulnerable to flooding. The highest point is 1,391 m amsl.

137. The gauging station at Battambang Town gauges some 3,230 km² of the basin.

8.1.5. Stung Pursat Basin

138. The Stung Pursat basin is one of basins in the Tonle Sap Basin Group (**Figure 15**). The Stung Pursat basin drains from south to north and has a basin area of 5,964 km² before discharging into the Tonle Sap Great Lake. The Stung Pursat River originates in the drier eastern slopes of the Cardamom Mountain Ranges and flows for approximately 150 km, ultimately draining into the Tonle Sap Great Lake. The basin ranges in elevation from 6 m to 1,717 m amsl (**Figure 15 A**). More than 75% of the basin consists of hilly terrain with an elevation above 30 m amsl. Two main tributaries, the Stung Peam and Stung Santre (Prey Khlong) rivers, flow in a northerly direction, and meet the Pursat River just above Bac Trakuon. The drainage area at Bac Trakuon, just below the confluence of the Pursat and the two tributaries is 4,245 km², and 4,596 km² farther downstream at the Khum Veal gauging station, located near the town of Pursat.

139. A number of dams and diversions have been constructed to support irrigated rice protection as well as to provide flood protection (**Figure 15 B**). The main diversion structures are Damnak Chheukrom and Damnak Ampil schemes, from where excess water and surface runoff are drained towards the Stung Kambot and Svay Donkeo rivers, which are located outside the Pursat basin. During the high flood period, the flood affected area is larger than 5964 km^2 as the flood area extends to Stung Kambot and some parts of Stung Svay Donkeo basins. From Bak Trakuon to Khum Veal, the Stung Pursat River losses about 60% of its peak flood, partly through exiting intake canal on the left bank (Damnak Ampil), partly due to channel storage., and partly due to under natural conditions. The overbank flood flow passes through Stung Kambot, O Ta Poang, and Stung Svay Donkeo, which later flow to the Stung Dauntry before discharging into the Tonle Sap Great Lake.

140. Affected by a rain shadow from the Cardamom Mountainous range, the Pursat river basin is known as a severely affected basin for both floods and droughts. The basin receives a mean annual rainfall of 1,390 mm. The maximum annual rainfall observed was 2,080 mm and the minimum was 870 mm. Rainfall amounts increase with basin elevation. The mean annual flow is 2,130 million cubic metres.

141. The population of the basin is approximately 203,500 persons (2008), who live in 29 communes with 223 villages. People living close to the lake earn their livelihood from fishing, while those further away depend on rice cultivation.

142. Droughts frequently occur, affecting most of the basin while flash floods occur in both upstream and downstream parts of the basin. The lowest part of the basin is vulnerable to both flash flood and overland flooding from the Tonle Sap Great Lake.

143. The major floods, which inundated the Pursat town, occurred in 2000, 2006, 2011, and 2012.

A **B**

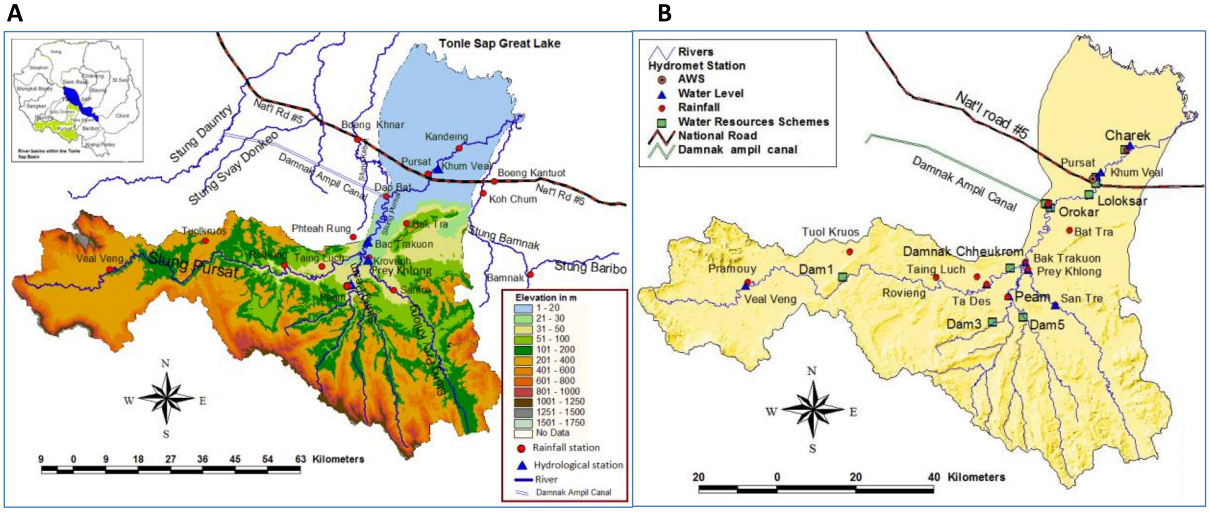


Figure 15: Stung Pursat basin showing Elevation, Hydromet stations and Water Resources Development

8.2. 3S Rivers Basin

144. The 3S River basin is composed of the Se Kong, Se San, and Sre Pok rivers. The 3S River basin is located in the northeast part of Cambodia and drains to the Mekong at Stung Treng. The basin is an international river basin shared between Cambodia, Lao PDR, and Vietnam. The total basin area is approximately 79,300 km^2 of which Cambodia, the most downstream country, has some 25,965 km^2 or 33% of the total area, Lao PDR 29%, and Vietnam 38%.

8.2.1. Se Kong Basin

145. The Se Kong basin (Number 31 in **Figure 3**) in Cambodia covers an area of 5,564 km^2 of the 32,200 km^2 basin area. The Se Kong river rises in the Annamite mountain range at the border between Lao PDR and Vietnam, and also drains the eastern part of the Bolovens Plateau east of Pakse. The Se Kong river travels for 344 km in Lao PDR, then some 155 km in Cambodia before meeting the Se San near Stung Treng Provincial Town and finally discharges into the Mekong. Four main tributaries the Prek Smang, Prek Khampha, Prek Kheh, and Prek Nakalaeng drain directly to the Se Kong River.

146. The Se Kong river is a young dynamic river with a number of rapids. There is no significant agri-water sector development within the basin. Crop production is mainly rain fed and the use of water in this sector is still low with a present water extraction estimated at 2 MCM. Domestic use is approaching 2 MCM per year.

147. The hydrological regime has been modified by upstream development with one hydropower plant in operation, three under construction, eight in the design stage, and nine at the planning stage.

148. Changes to the Se Kong river have been noted. The changes include the river has become shallower and the appearance of small islands more apparent, an increase in water pollution has been observed, and vegetation along the river bank has been significantly reduced.

8.2.2. Se San Basin

149. The Se San basin (Number 30 in **Figure 3**) in Cambodia covers an area of 8,021 km^2. The total basin area is 17,300 km^2, which includes the Viet Nam portion. The Se San river rises in the Truong Son Mountain Range of Central Vietnam and flows for over 200 km before entering Cambodia. In Cambodia, the Se San flows for 278 km before discharging into the Se Kong river at Stung Treng. In Cambodia, seven tributaries, namely, Prek Chhnang, O Kan Sieng, Prek Lalai, Prek Banpang, O Ta Phlay, Prek Lamong, and Prek Liang drain into the Se San river.

150. The Se San river is one of the largest tributaries to the Mekong. Its high flows tend to start later in the year in comparison to other tributaries and it maintains flows later into the dry season. This flow characteristic is important for maintaining high Mekong flows later in the wet season.

151. The Se San is regulated due to hydropower development. It is important to note that flows of the Se San have become less predictable in recent years. A major issue faced by the Se San's riverine population is

the cumulative impacts from upstream developments, which are trans-boundary. Hydropower development consists of six hydropower schemes in operation (1,170 MW Viet Nam), one under construction (360 MW, Viet Nam), one at the design stage (250 MW, Viet Nam), and five at the planning stage (823 MW, Vietnam and Cambodia). The upstream cascade dams in Vietnam are having a significant impact on the important and high valued fish spawning areas in the basin.

152. In Cambodia, the Sesan 2 - Sre Pok 2 Hydropower plant, which is under construction, has caused concern from the affected communities. Other planned hydropower projects in the basin are the Lower Sesan 3, Lower Sesan 1, Prek Liang 1, and Prek Liang 2.

153. There are several irrigation schemes in the basin and agricultural expansion is underway. As well, increased urbanization and mining are placing pressure on the water resource in the basin.

8.2.3. Sre Pok Basin

154. The Sre Pok river (Number 29 in **Figure 3**) rises in Central Vietnam and flows for 250 km within Cambodia before joining the Se San some 30 km upstream of the confluence of the Se San with the Se Kong. In Cambodia, the Sre Pok river gathers water from eleven tributaries namely O Kaong, O Patinh Thum, Prek Dokyong, Prek Drang, Prek Nam Lieou, Prek Rue, O Phlay, Prek Rouei, Prek Tramet, Prek Chbar, and Prek Dak Dam.

155. The Sre Pok basin in Cambodia is 12,380 km^2, representing some 42 % of the 29,800 km^2 basin area.

156. The Sre Pok river is one of the largest tributaries to the Mekong. Its flow characteristics are similar to the Se San and Se Kong. The risk of flooding in Sre Pok is high, especially late in the wet season due to storms such as Typhoon Ketsana, which can cause significant damage and loss of life.

157. The flow of the river has been modified with significant upstream hydropower development in Vietnamese. There are two hydropower schemes in operation (28 MW), five schemes under construction (656 MW), and three schemes in the planning stage (400 MW).

8.3. Prek Thnot

158. The Prek Thnot basin (Number 11 in **Figure 3**) covers an area of 6,243 km^2. The river originates in the Cardamom mountain range, which are located in southwest part of the country and flows in west-east direction for total length of about 226 km. At about two third of its total length, the Prek Thnot river passes the Kampong Speu town and travels for another one third before discharging into the Bassac river at Takmao Town, which is located about 9 km downstream of Chaktomuk (Phnom Penh). There are seven main tributaries that flow into the Prek Thnot river, including Stung Aveang, Stung Trong Krang, Stung Tasal (Prek Banchar + Stung Thom + Stung Tasal), Stung Phleach, Stung Tang Haong (Tang Haong + Stung Sva Slab, O Khlei), and O Krang Ambel.

159. The Prek Thnot basin is influenced by the shadow effect of the Cardamom mountain range, characterized by irregular rainfall, extreme droughts, and flash flood conditiosn. Flash floosd from this basin often threatens the new southern Phnom Penh industrial zone, including the Kampong Speu provincial town and surrounding area, the railway line, and National Road 3 (NR3) and NR2.

160. The implementation of the Prek Thnot multi-purpose development project for hydropower (18MW), irrigation (70,000ha), and flood control was interrupted by war in 1973. After 1992, attempts have been unsuccessful to reactivate the project due to severe social and environmental problems. As of 2016, only part of the project component has been implemented, namely the water head regulator at Roleang Chrey (rehabilitated after the war), part of the two main canals on the left and right banks distributing run-off type water. For the NR3, one spillway and flood control sluice gates (JICA assistance) at Kampong Tuol and a control gate and flood diversion canal across the NR2 have been completed.

161. The main gauging station is located at Peam Khley about 12 km upstream of Roleang Chrey. The downstream station is at Thnuos Luong bridge of NR 4 next to Kampong Speu town.

8.4. Mekong Mainstream

162. The Cambodian Mekong mainstream system, including the Bassac and the Tonle Sap Great Lake, forms the most productive part of the Mekong basin and supports the highest population densities. The system provides a critical flood attenuation function that is potentially threatened by flood plain development and loss of flood conveyance due to infrastructure.

163. The Cambodian Mekong delta is a very large floodplain consisting of complex river systems connecting numerous lakes and depressions with the mainstreams system. Its hydrological conditions are dominated by the Mekong flow regime characterized by significant seasonality and year-to-year variability in river flow. Phnom Penh is located at the junction of the four main river branches, the Upper Mekong, the Lower Mekong, the Bassac river, and the Tonle Sap river. The Tonle Sap river connects the Tonle Sap Great Lake to the Mekong.

164. There are ten operational gauging stations on the mainstream rivers, Mekong, Bassac, and Tonle Sap. Seven of these stations are located at major towns for flood monitoring by the Department of Hydrology and River Works (DHRW). The stations are located at Stung Treng, Kratie, Kampong Cham, and Neak Leung on the Mekong, at Phnom Penh Chaktomuk and Koh Khel on the Bassac river, and at Prek Kdam on the Tonle Sap river.

165. A schematic of the Mekong system in Cambodia is shown in **Figure 16**. The schematic highlights the gauging and forecast points as well as the location of additional stations.

166. Multi and single-regression models have been applied by DHRW to prepare flood level forecasts for the seven stations.

167. MOWRAM has suggested that the mainstream Mekong be selected as one of the two priority basins. The reason for selecting the mainstream Mekong is driven from MOWRAM's desire to enhance NFFC's flood forecasts for the mainstream Mekong in both accuracy and forecast horizon.

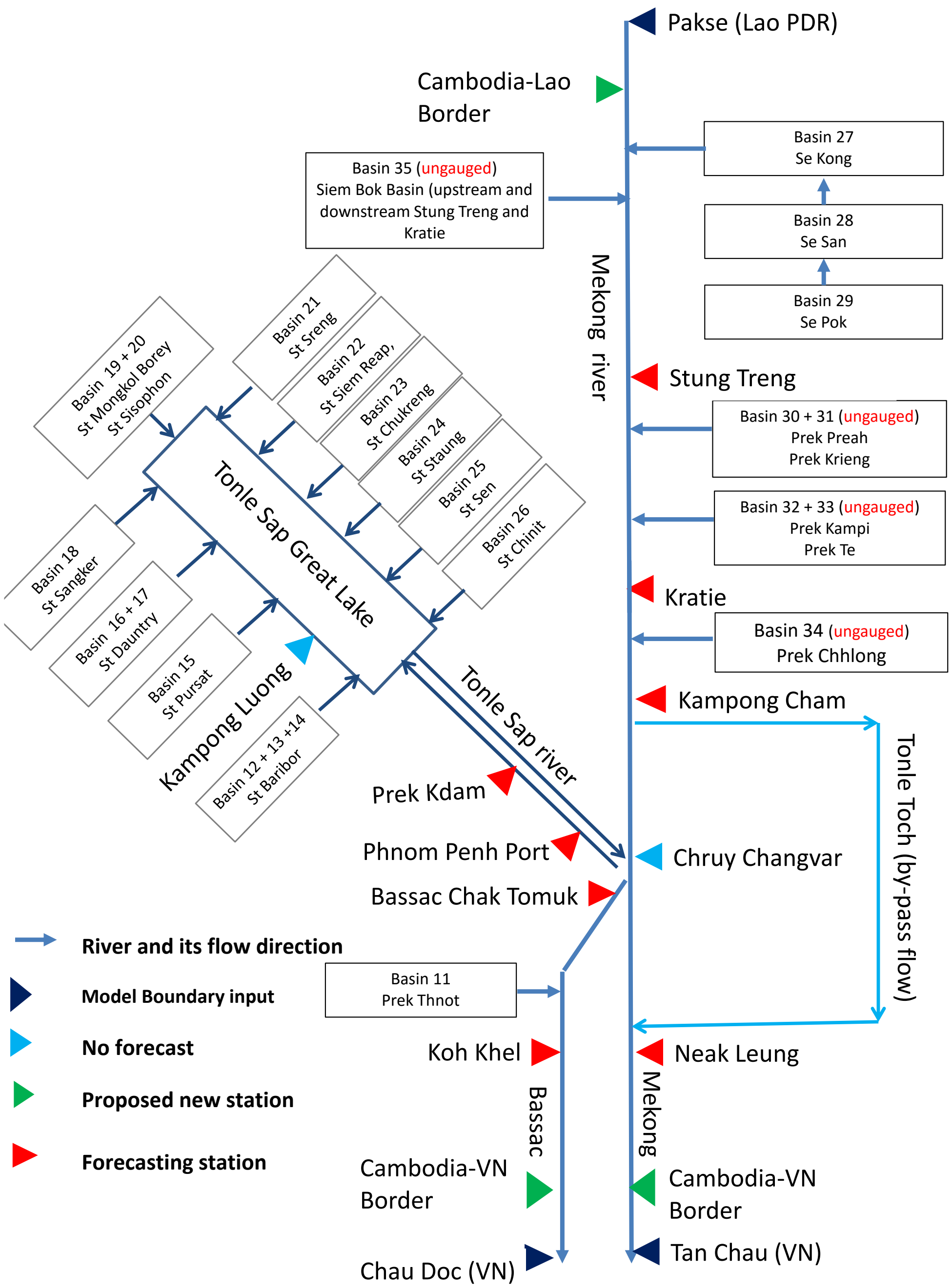


Figure 16: Mekong basin diagram - Cambodia

9. Conclusions

168. Throughout the preceding sections, information on flood and drought risks in Cambodia have been presented. From the studies reviewed, various methodologies and criteria have been used to characterize and define flood and drought risk areas in Cambodia.

169. Using the results and findings of these studies, flood and drought vulnerable basins were identified. The factors considered were the availability of data and information, the severity of the event, the frequency of the event, population, economic importance, size of existing and planned investment, and agricultural significant areas.

170. The studies clearly lead to the conclusion that floods and droughts affect a significant large area of Cambodia. Therefore, no one or two priority basins emerged from the analysis of the available data and information.

171. Given this result, a number of basins vulnerable to both floods and droughts have been identified for consideration based on the review of the studies and investigations noted in this report as well based on the professional experience of the team. These basins have been described in some detail in Section 8.

172. Through consultations with MOWRAM, two basins have been identified as the focus for the activities under the NFFC project that are being conducted to improve the National Flood Forecasting Centre (NFFC) and to propose climate resilient design guidelines for structural flood and drought mitigation.

173. The two basins are the Stung Pursat basin and the mainstream Mekong basin.

174. Accordingly, improvements for flood forecasts and drought predictions will be investigate for the two basins.

175. However, due to the significant complexity of modelling mainstream rivers and the significant area covered by flood events, the mainstream Mekong does not lend itself to the detailed assessment of flood and drought hazards and the associated assessment of risks within the contract's twenty-four month duration.

176. Therefore, the detailed investigation for the development of design guidelines for climate resilient structures will be limited to the Stung Pursat basin. It is believed that using the Pursat basin will not constrain, nor limit, the development, scope, and application of the proposed design guidelines.

10. References

ADB, 2012: Flood Damage Emergency Reconstruction Project: Preliminary Damage and Loss Assessment.

ADB TA 6456-REG, 2010. Preparing the Greater Mekong Sub-region Flood and Drought Risk Management and Mitigation Project, Final Main Report- Cambodia.

CDRI, 2014. Methods and Tools Applied for Climate Change Vulnerability and Adaptation Assessment in Cambodia's Tonle Sap Basin. Working paper No. 97

CHF (USAID/PADEK/ADPC), 2012: "Strengthening Emergency Response Capacity of Humanitarian NGOs in Cambodia",

ERI-DP, 2013. Impact of Disasters and Role of Social Protection in Natural Disaster Risk Management in Cambodia

MOWRAM/ADB, 2015, CDTA 7610-CAM: "Institutional Arrangements for the Management of Water Resources in Cambodia"

MOWRAM/ADB, 2014, CDTA 7610-CAM: "Cambodia Water Resources profile"

MRC, 2012. The Impact and Management of Floods and Droughts in the Lower Mekong Basin and the Implication of possible Climate Change. Working Paper (2011-2015).

MRC, 2010. Impacts of climate change and development on Mekong flow regimes. First Assessment, Technical paper No.29.

MRC's FMMP (FMMP-C2), 2010: "Structural Measures and Flood Proofing", the "Best Practice Guidelines for Flood Risk Assessment".

MRC, 2009. Adaptation to climate change in the countries of the Lower Mekong Basin: Regional Synthesis Report, Technical paper No.4.

NCDM, 2014. National and Provincial Risk Assessment, Cambodia 2014. "Strengthening the Disaster Management Systems in Cambodia through Risk Assessment, Early Warning Systems, and Developing Building Codes"

NCDM, 2010. Post Ketsana Disaster Needs Assessment.

NCDM/MOP: Strategic National Action Plan for Disaster Risk Reduction 2008 – 2013

NCDM/UNWFP, 2003. Mapping Vulnerability to Natural Disasters in Cambodia.

Leng H. A., NCDM, 2014, Country Report of Cambodia on Disaster Management.

UNDP, 1994: "Vulnerability and Risk Assessment", Disaster Management Training Program