Climate Change Adaptation in Urban Development (Package 2)

Integrated Urban Environmental Management in the

Tonle Sap Basin Project (Tonle Sap 1)

ADB Grant : 0454-CAM

Provincial Climate Change Adaptation Strategy around Tonle Sap

Final Report

Prepared for

Ministry of Public Works and Transport (MPWT)

Cambodia

December 2018

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PREAMBLE

1. The Tonle Sap Basin of Cambodia is situated in the middle of the GMS southern corridor that runs from Bangkok, Thailand through Cambodia to Ho Chi Minh City in Vietnam. The towns around Tonle Sap Lake are key locations for growth based on the economic corridor, upgraded and new transport routes, and tourism.

2. The Tonle Sap Urban Areas Development Framework was produced in June 2014. The TSUADF is intended to provide a rationale and guideline for the sustainable growth of the urban areas that lie within the vicinity of the Tonle Sap lake. Urban areas are the focal points of economic growth and will be crucial to the development of the area as a whole. At the same time urban development can have potentially adverse impacts on the water resource and the environment surrounding it.

3. The ADB funded “Integrated Urban Environmental Management in the Tonle Sap Basin Project” (IUEMTSBP) is responding to the needs of the municipal governments for significant improvements in urban infrastructure around the Tonle Sap lake. This will contribute to increased economic activities and environmental protection in towns in and around Tonle Sap. Key subprojects are sanitation, waste water treatment, flood protection and solid waste management under the Ministry of Public Works and Transport.

4. Under Tranche 1 the IUEMTSBP will improve urban services and enhance climate change resilience in Kampong Chhnang and Pursat municipalities through urban area environmental improvements; community mobilization and environmental improvements; strengthened sector coordination and operations; and strengthened capacity for project implementation.

5. Extensive use was made of the Flood Risk Management Interface (FRMI) software made available by Ministry of Public Works and Transport and their cooperation is gratefully acknowledged.

6. This report examines in detail two of the provinces around TLS and then extends the findings on climate change to the other four provinces.

7. Data was obtained from MOWRAM for daily rainfall going back 30 years for 19 provinces and hourly rainfall for 11 provinces going back 4 years.

8. A strategy has been developed for the 6 provinces around Tonle Sap lake to incorporate climate resilience in their designs.

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Abbreviations

AASHTO American Association of State Highway and Transportation Officials

ADB Asian Development Bank

CIF Climate Investment Fund

CTF Clean Technology Fund

DEM Digital Elevation Model

DGPS Differential Global Positioning System

EXIM Export Import Bank of Korea

FRMI Flood Risk Management Interface

GCM Global Circulation Models

GIS Geographic Information System

GTFM Generalized Tropical Flood Model

IDF Rainfall Intensity Duration and Frequency curves

KM Knowledge Management

MRD Ministry of Rural Development

MOWRAM Ministry of Water Resources and Meteorology

MPWT Ministry of Public Works and Transport

MRC Mekong River Commission

PMU3 Project Management Unit 3

PPCR Pilot Program for Climate Resilience

PRIP Provincial Roads Improvement Project

RCP Representative Concentration Pathway

SCF Strategic Climate Fund

SPCR Strategic Program for Climate Resilience

1. EXECUTIVE SUMMARY

9. The Tonle Sap Basin of Cambodia is situated in the middle of the GMS southern corridor that runs from Bangkok, Thailand through Cambodia to Ho Chi Minh City in Vietnam.

10. The towns around Tonle Sap Lake are key locations for growth based on the economic corridor, upgraded and new transport routes, and tourism.

11. The ADB funded "Integrated Urban Environmental Management in the Tonle Sap Basin Project" (IUEMTSBP) is responding to the need of the municipal governments for significant improvements in urban infrastructure around the Tonle Sap. This project will contribute to increased economic activities and environmental protection in towns in and around Tonle Sap.

12. Under Tranche 1 the IUEMTSBP will improve urban services and enhance climate change resilience in Kampong Chhnang and Pursat municipalities through urban area environmental improvements; community mobilization and environmental improvements; strengthened sector coordination and operations; and strengthened capacity for project implementation.

13. Tonle Sap is at risk of being adversely affected by climate-induced changes to the Mekong River and its tributaries. About 62% of the Tonle Sap's water originates in the Mekong River and 38% in the Tonle Sap basin. Average water levels in the Tonle Sap may rise by 0.2 m and peak water levels may increase by up to 0.3 m by 2050, so floods may last 9% longer as a result of climate change impacts and the probability of river floods is likely to increase. This is primarily due to earlier snow melt in the upper reaches of the Mekong in China and more intense rainfall.

14. A countervailing effect is the creation of dams in the upstream reaches of the Mekong and more diverted flows for irrigation. This could lower flows in the Mekong and both these factors together create a large element of uncertainty in future predictions.

15. The TOR requires us to make revisions to the Building Code. We are informed that the Building Code is under revision by the Ministry of Land Management, Urban Planning and Construction and no Cambodian Building Code seems to exist at the moment. Nonetheless recommendations on appropriate sanitation and latrine facilities have been made.

16. The Tonle Sap Basin has an Urban Development Framework which guides sustainable growth and climate resilient infrastructure development.

17. There are many policy initiatives on Climate Change in Cambodia. Climate Change Action Plans have been prepared for many ministries and sectors.

18. There are at least four separate recent climate change projections for the Tonle Sap area. Not all projections contain the same parameters but a comparison can be made.

Table 1-1 Comparison of Climate Change Projections from Various Sources

Parameter	Season	USAID 2013	MOWRAM 2014	Battambang 2015	Pursat extrapolated from Battambang	Average
Rainfall	Wet Season	+8%	+4%	+8%	+7.5%	+6.9%

	Dry Season	+1-2mm		-2.5%	-4%	-3.25%
Temperature	Wet Season	+3.2ºC	+1.7ºC	+2.6ºC	+3.5ºC	+2.5ºC
	Dry Season	+2.6ºC		+1.9ºC		+1.75ºC
Floods	Wet Season	No change	+9%			+9%
Drought	Dry Season	+15 days	+6 days			+10.5 days

19. From the above it can be seen that wet season rainfall may increase by 7%, dry season rainfall may drop -3%, wet season temperatures may increase by +2.5ºC and dry season temperatures by +1.75ºC. Flood occurrences and duration may increase by 9% and dry spells increase by 10 days. These projections are for the year 2050 under the A1B scenario which approximates to RCP6.0.

20. Uncertainty is a major consideration. There are at least three different and contrary factors to consider:

- more rain in the Tonle Sap basin due to climate change
- more flow in the Mekong river due to upstream earlier snow melt
- less flow in the Mekong river due to upstream hydro dams

All of these add to uncertainty in choosing parameters for design.

21. The MPWT software FRMI gives flood risks. It is only targeted at road segments but it does cover the whole of Cambodia. The projections given in the FRMI software are based on current conditions and future values for 2055 under a high CO_2 climate change scenario which is RCP 8.5. They are a "broad brush" approach and one value can relate to upwards of 10kms of road. However, they do cover the whole of Cambodia and despite limitations on their accuracy are considered useful.

22. The NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) were developed in support of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5). The NEX-GDDP dataset includes RCP 4.5 and RCP 8.5 and gives daily maximum temperature, minimum temperature, and precipitation for the periods from 1950 through 2100. The data covers the entire earth at a resolution of 0.25 degrees (~25 km x 25 km) and has been used in this report.

23. Some projections have been made for RCP6.0 and some for RCP8.5. The projections indicate that when extending out to 2050 and beyond there is not much difference between results for RCP 6.0 and RCP 8.5.

24. The main conclusions on precipitation are:

- Annual rainfall may remain unchanged but rainfall will increase more in the wettest months by being of stronger duration. This will lead to longer dry periods. There may be "mini-droughts" during the wet season.
- Precipitation will increase most in the south-west and decrease in the north-east.

- Both the maximum 5-day and 1-day storms are expected to increase. The projected increases are 10% for 2030, 20% for 2050 and 30% or more for 2070.
- The relative increase in rainfall is heavier for short durations.

25. If hourly or short term data on rainfall is lacking daily rainfall figures can be used to estimate hourly rainfall for drainage design calculations. In general, the one hourly rainfall figure is 20-40% of daily although figures of 60% have been recorded around Phnom Penh. When in doubt a higher figure should be used.

26. Based on actual short term rainfall measurements there is significant variation across the country with some provinces experiencing almost twice the short term intensity of other provinces.

27. Short term data recorded by MOWRAM for Kampong Thom indicates 50mm per hour. Data for Banthey Meanchey indicates over 90mm per hour. The former figure (50mm/hr) is typical of a heavy downpour and the latter figure (90mm/hr) signifies extremely heavy rain.

28. "*Extremely heavy rain*" is usually the descriptor for rainfall of 200mm / day or higher. If 90mm is falling in one hour then the factor of 50% applies, that is to say it is very plausible that 50% of a daily rainfall occurs in one hour. This is supported by the measured data from Pochentong Airport.

29. It is recommended that if daily rainfall is known then a figure of 50% of the daily rainfall be taken as the peak hourly rainfall. This is conservative.

30. There is a pronounced difference in historical and projects IDFs around Tonle Sap. IDFs have been given for each province. (See Annex 3) These should be used in design.

31. For a common design event, say a 1 in 10 year storm, in the future under RCP4.5 which is an optimistic scenario, for :

- Kampong Chhnang; precipitation will remain the same
- Pursat: precipitation will go down by 6%
- Battambang; precipitation will go down by 26%
- Serei Sisophon; precipitation will go up by 26%
- Siem Reap; precipitation will go down by 34%
- Kampong Thom; precipitation will go up by 15%

32. Also for an extreme event say a 1 in 100 year storm in the future under RCP4.5 which is an optimistic scenario, for :

- Kampong Chhnang; precipitation will go down by 4%
- Pursat; precipitation will go down by 10%
- Battambang; precipitation will go down by 29%
- Serei Sisophon; precipitation will go up by 25%
- Siem Reap; precipitation will go down by 41%
- Kampong Thom; precipitation will go up by 19%

33. The correction factors for RCP8.5 are different as this is a pessimistic scenario.

34. For a common design event say a 1 in 10 year storm in the future under RCP8.5 for :

- Kampong Chhnang; precipitation will go up by 17%
- Pursat: precipitation will go up by 26%
- Battambang; precipitation will go up by 8%
- Serei Sisophon; precipitation will go up by 10%
- Siem Reap; precipitation will go up by 8%
- Kampong Thom; precipitation will go up by 28%

35. Also for an extreme event say a 1 in 100 year storm in the future under RCP8.5 which is an pessimistic scenario, for :

- Kampong Chhnang; precipitation will go up by 16%
- Pursat; precipitation will go up by 34%
- Battambang; precipitation will go up by 12%
- Serei Sisophon; precipitation will go up by 12%
- Siem Reap; precipitation will go up by 11%
- Kampong Thom; precipitation will go up by 32%

36. As this is a pessimistic scenario increases in short term precipitation can be expected. All sites will experience an increase in short storm intensity, by a maximum of 34%.

37. This factor should be applied to the IDF curves in detailed design. The full range of IDF curves for all provinces in Cambodia is given in Annex 3.

38. The total cost of climate change adaptation measures in TLS2 are $3,185,000 out of a total project cost of US$82.2 million or 3.8%.

39. The total cost of climate change adaptation measures in TLS1 are still under review.

40. A flow chart for implementation of the Climate Resilience Strategy is given. (Figure 22-11) This strategy was delivered to the Provincial Government representatives in a workshop and well received.

2. INTRODUCTION

2.1. The Tonle Sap Basin

41. The ADB funded “Integrated Urban Environmental Management in the Tonle Sap Basin Project” (IUEMTSBP) is responding to the needs of the municipal governments for significant improvements in urban infrastructure around the Tonle Sap. This project will contribute to increased economic activities and environmental protection in towns in and around Tonle Sap.

42. The Tonle Sap Basin of Cambodia is situated in the middle of the GMS southern corridor that runs from Bangkok, Thailand through Cambodia to Ho Chi Minh City in Vietnam.

Figure 2-1 GMS Corridors

43. The towns around Tonle Sap Lake are key locations for growth based on the economic corridor, upgraded and new transport routes, and tourism.

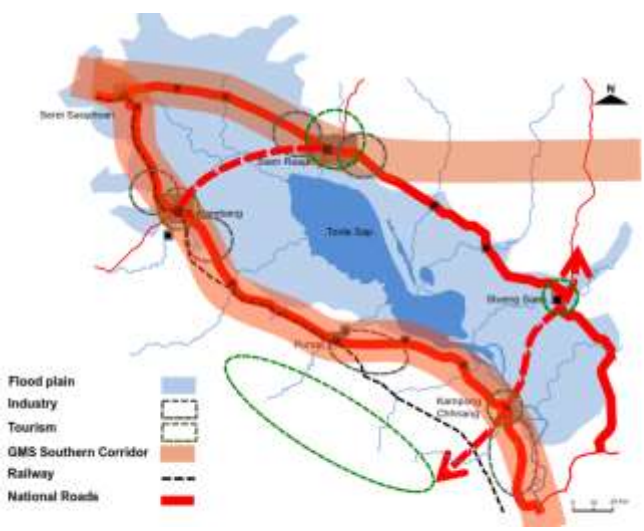


Figure 2-2 Strategic Importance of TLS

2.2. Greater Mekong Subregion Urban Development Strategic Framework 2015–2022

44. The Greater Mekong Subregion (GMS) Urban Development Strategic Framework, 2015-2022 sets out a broad framework to encourage and facilitate a coordinated approach to the development of urban areas throughout the GMS. The framework includes three pillars: (i) planning and development of key urban areas, (ii) planning and development of border areas, and (iii) capacity development in urban planning and management. Underlying these are four crosscutting themes—green development and climate change resilience, disaster risk management, inclusive development, and competitiveness. The GMS Urban Development Strategic Framework also provides the context for ongoing and planned projects in the six GMS member countries. The projects for Cambodia are shown below.

Key:
□ Moderate contribution
■ Strong contribution

Project or Activity (ADB, unless stated otherwise)	Location	Urban Centers	Border Area	Capacity Development	Green Development	Multi-Country	GMS Corridor
Approved and Forthcoming Projects							
Cambodia							
Urban Water Supply	Countrywide	■					
Capacity Development for Urban Management	Countrywide			■	□		
Integrated Urban Environmental Management in the Tonle Sap Basin	Pursat, Kampong Chhnang, Tonle Sap	■		■	□		■
Urban Water Supply Systems (JICA)	Battambang, Kampong Cham, Kampong Thom, Kampot, Pursat, Siem Reap, Sihanoukville, Svay Rieng	■					■
National Road No. 5 Improvement Project (JICA)	Battambang to Serei Saophoan	□					■
Greater Phnom Penh Water Supply System (AFD)	Phnom Penh	■			□		■

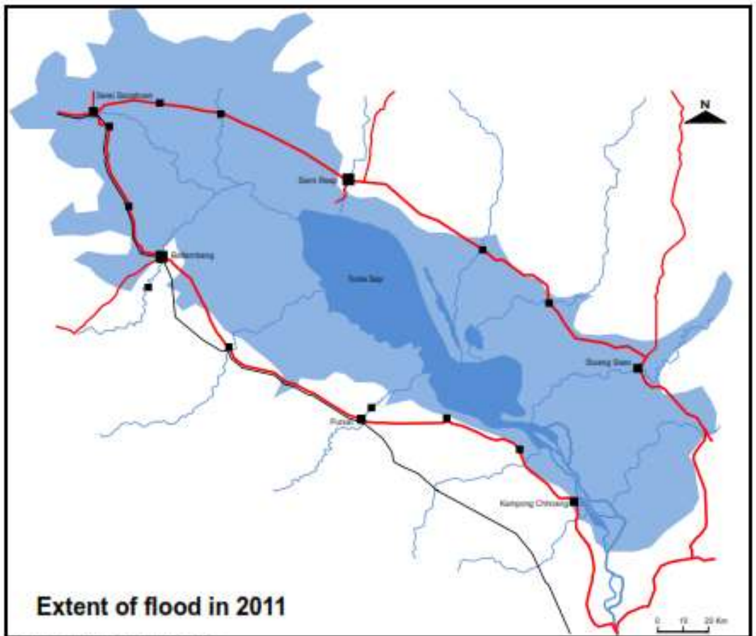
Figure 2-3 GMS Urban Development Strategic Framework Projects for Cambodia

2.3. Integrated Urban Environmental Management in the Tonle Sap Basin

45. The Tonle Sap Urban Areas Development Framework was produced in June 2014. The TSUADF is intended to provide a rationale and guideline for the sustainable growth of the urban areas that lie within the vicinity of the Tonle Sap lake. Urban areas are the focal points of economic growth and will be crucial to the development of the area as a whole. At the same time urban development can have potentially adverse impacts on the water resource and the environment surrounding it.

46. The urban areas around the Tonle Sap are all located on rivers that flow into the lake. Urban waste and other forms of pollution entering the rivers therefore end up in the lake. In addition, the annual flood of the lake penetrates urban areas. When the floods recede they take with them liquid and solid wastes accumulated during the flood. Key subprojects are sanitation, waste water treatment, flood protection and solid waste management.

47. One project is the Integrated Urban Environmental Management in the Tonle Sap Basin under the Ministry of Public Works and Transport.



Source: UNITAR/UNOSAT

Figure 2-4 Rivers around TLS and Extent of Annual Flood

48. Under Tranche 1 the IUEMTSBP will improve urban services and enhance climate change resilience in Kampong Chhnang and Pursat municipalities through urban area environmental improvements; community mobilization and environmental improvements; strengthened sector coordination and operations; and strengthened capacity for project implementation. This study also applies to other provinces around TLS.

2.4. Tonle Sap Cambodia

49. Tonle Sap literally means large river (*tonle*) of freshwater (*sap*)" but is generally accepted as meaning "Great Lake". The volume of water in the lake is driven by three factors:

- Rain falling onto the lake itself
- Rain water runoff from the nearby Cardamon mountains and the Dangrek Escapment flowing into the lake
- Water of the Mekong river which when higher than the lake pushes the surplus rain water back into the Tonle Sap lake causing water levels in it to rise and expand

50. When levels in the Mekong drop, the flow in the Tonle Sap River, which connects the lake to the Mekong, reverses its flow. In recognition of its unique ecological phenomenon and the rich inherent biodiversity, in 1997 the lake was designated as a protected area under UNESCO's Man and Biosphere programme.

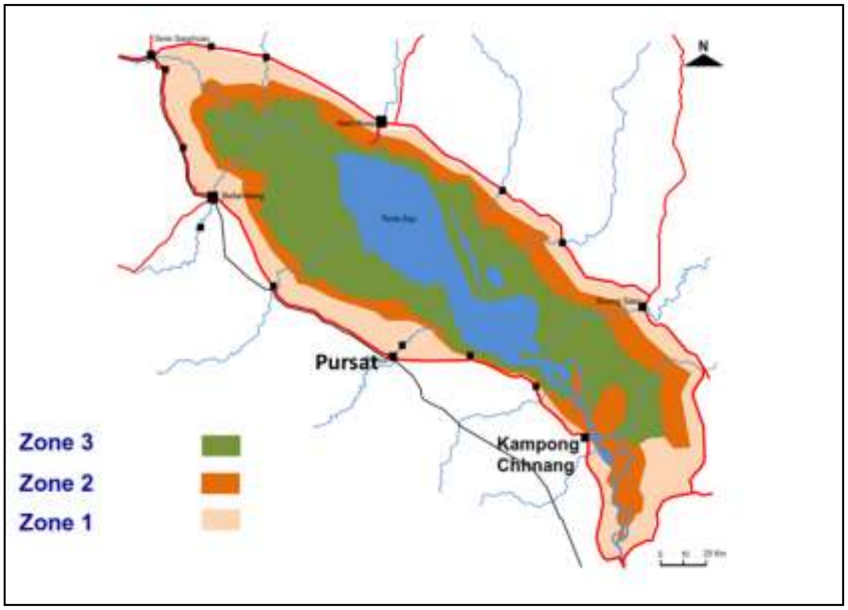


Figure 2-5 TLS Protected Zones

51. It is the largest lake in South East Asia and changes in size and dimension every wet season. It has a minimum size of 2,800 km² and about 1 m depth during the dry season. In the wet season the lake is transformed into a natural water reservoir and the lake's size increases to approximately 15,000 km² with a depth of 8 m. In flood it covers nearly 10% of Cambodia’s land area.

52. This more than quadrupling of the surface area means the population have adapted to changing living conditions. There are floating villages where whole communities move and some houses have very unusual structures.

Figure 2-6 House at Prek Toal bird sanctuary northern end of TLS

53. The lake is bounded by NR5 to the west and NR 6 to the east and surrounded by the six Tonle Sap provinces of Kampong Chhnang, Pursat, Battambang, Banteay Meanchey, Siem Reap and Kampong Thom.

Figure 2-7 Tonle Sap and Surrounding Provinces

54. Each of the provinces has an administrative provincial capital which has become an urban centre. About 12% of the population in the Tonle Sap provinces live in urban areas along Highways No. 5 and 6 and the six largest urban areas had an estimated population of 480,000 in 2012 and is anticipated to grow to 670,000 by 2030.

2.5. Climate Change and Human Impacts

55. Tonle Sap is at risk of being adversely affected by climate-induced changes to the Mekong River and its tributaries. About 62% of the Tonle Sap's water originates in the Mekong River and 38% in the Tonle Sap basin. Average water levels in the Tonle Sap may rise by 0.2 m and peak water levels may increase by up to 0.3 m by 2050, so floods may last 9% longer as a result of climate change impacts and the probability of river floods is likely to increase. This is primarily due to earlier snow melt in the upper reaches of the Mekong in China and more intense rainfall.

56. A countervailing effect is the creation of dams in the upstream reaches of the Mekong and more diverted flows for irrigation. This could lower flows in the Mekong and both these factors together create a large element of uncertainty in future predictions.

2.6. Tonle Sap Urban Areas Development Framework (TSUADF)

57. The TSUADF guides sustainable growth and climate resilient infrastructure development of urban areas in the Tonle Sap Basin. It helps ensure coherence in implementation on issues of integrated spatial planning, urban management and governance, effective and efficient public services to residents, urban area competitiveness and growth, climate change adaption, social and economic well-being and inclusion, and green cities development.

2.7. ADB's Approach to Climate Change

58. From 2011 to 2015, ADB approved over $15.5 billion of climate financing. In 2016 ADB approved a further $3.7 billion in climate finance investments representing a 42% increase over 2015.[1]

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[1] *ADB's Focus on Climate Change and Disaster Risk Management, WWW.AB.ORG, 2017*

2.8. Impact of Climate Change on Economy of Cambodia

Cambodia is ranked as one of the most climate-vulnerable countries in the world. The Climate Risk Index ranked Cambodia 13th out of 181 countries.[2]

Cambodia is highly vulnerable to the impacts of climate change because the kingdom depends largely on climate-sensitive sectors including agriculture, land, water resources, forestry and fisheries.[3] Rural households, especially women and other vulnerable groups, are most impacted.

According to ADB in 2015 Cambodia lost $1.5 billion from negative effects of climate change which equates to 10% of its gross domestic product (GDP).[4]

The Cambodia Disaster Loss and Damage Analysis Report describes the disasters that have occurred in Cambodia from 1996 to 2013: These have been : flood (42%), drought (15%), fire (17%), storm (14%), lightning (7%) and pest outbreak (1%). During this period, disasters killed 2,050 people. Floods accounted for 53% of the total number lost.[5]

USAID applied climate projections for 2050 to current Mekong Basin economies and found that future climate change could put up to 61% of Cambodia's rural GDP per capita at risk. The 2050 climate projections would affect around 7 million Cambodians employed in the agricultural sector and about 240,000 in construction, causing a total economic impact of $1.5 billion.[6]

2.9. Reference Materials

59. Reference materials used in this project include :

- Sector Briefing on Climate Change Impacts and Adaptation: Water Supply and Sanitation ADB, January 2012.
- Guidelines For Climate Proofing Investment in the Water Sector : Water Supply And Sanitation, ADB 2016
- Mekong River Commission, Roads and Floods, MRC Technical Paper No. 35, 2011
- Climate Change Impact and Hydrology, MRD June 2013
- Climate Change Adaptation Options, MRD May 2014
- Climate Change Adaptation Report August, MRD, (Manley, R) August 2014
- Reinforcing Community Flood Resilience, MPWT, August 2014
- Report on Knowledge Management, MPWT, June 2015

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[2] *Arief A. Yusuf, Herminia A. Francisco. Mapping Analysis. Climate Change Vulnerability Mapping for Southeast Asia. EEPSEA: 2009. Accessed 5 May 2015.*

[3] *Ministry of Environment. Policy paper. Cambodia Climate Change Strategic Plan 2014 – 2023. Ministry of Environment: 2014. Accessed 5 May 2015.*

[4] *National Committee for Disaster Management (NCMD), ADB / UNDP Cambodia report. Cambodia Disaster Loss and Damage Analysis Report 1996 – 2013. 2014. Accessed 7 May 2015.*

[5] *http://www.kh.undp.org/content/dam/cambodia/docs/EnvEnergy/Cambodia-Disaster-Loss-and-Damage-Analysis-Report%201996-%202013.pdf.*

[6] *Talberth, John. Reytar, Katie. Climate Change in the Lower Mekong Basin. New York: United States Agency for International Development (USAID), 2014. Accessed 7 May 2015.*

- Non Mandatory Guidelines for Flood Proofing Roads, MPWT September 2015
- Road Design Standard Changes Report, MPWT September 2015
- Flood Risk Management Interface Manual, MPWT, September 2015
- Climate Change and Water Governance in Cambodia, Challenge and Perspectives for Water Security and Climate Change in Selected Catchments, Cambodia, Cambodia Development Resource Institute, Phnom Penh, December 2015.
- Climate Change Strategic Plan for Water Resources and Meteorology (2013-2017), Ministry of Water Resources and Meteorology, Phnom Penh, 2012
- Vulnerability Mapping Report, MPWT, January 2016
- Climate Modelling Report, MPWT, January 2016

3. CLIMATE CHANGE POLICIES IN CAMBODIA

3.1. National Environment Strategy and Action Plan (NESAP) 1998 / 2023

60. In 1998, Cambodia produced the National Environmental Action Plan covering 1998–2002. The NESAP will cover 2015–2023 to align with the country's Rectangular Strategy and National Strategic Development Plan. It will complement the new National Environmental Code, which focuses on establishing a stronger legal framework and is being developed concurrently to the NESAP.

61. NESAP is intended to provide a roadmap for natural resources and environment planning, ensuring effective environmental protection and sustainable use of natural resources through an inclusive and participatory process. The NESAP will guide government ministries, private sector, civil society, and development organizations to mainstream environmental considerations into development policies, plans, and investments.

3.2. National Policy on Green Growth (NPGG) 2013

62. The National Policy on Green Growth was approved by RGC on 1 March 2013. This policy is envisaged to strike a balance of economic development with environment, society, culture and sustainable use of national resources through integration, matching and adaptation as well as harmonization between a green growth principle and national policy. The goal of this policy aims at enhancing the well-being and livelihood of all people in harmonization with ecological safety through green growth, based on green economy, blue economy, environment protection, social safety nets system and uphold of national cultural identity.

63. The green growth Road Map focuses on all the sectors that are conducive for economic growth and environmental sustainability. The National Green Growth Roadmap focuses on addressing seven "A"'s:

- Access to clean water and sanitation
- Access to renewable energy
- Access to information and knowledge
- Access to means for better mobility
- Access to finance and investment
- Access to food security (agriculture) and non-chemical products; and
- Access to sustainable land-use

3.3. National Strategic Plan on Green Growth 2013-2030

64. National Strategic Plan on Green Growth 2013-2030 was adapted on 1 March 2013. **The Goal** of National Strategic Plan aims at green growth, ensuring politic stability and macroeconomic stability to reach a status of a developed country.

65. Objectives of the National Strategic Plan is to promote a national economy with growth stability, reduction and prevention of environmental pollution, safe ecosystem, poverty reduction, and promotion of public health service, educational quality, natural resources management, and sustainable land use and water resources management to increase energy efficiency, ensuring food safety and glorify the national culture.

3.4. National Adaptation Program of Action to Climate Change (NAPA) 2006 / 2012

66. The main goal of the NAPA is to provide a framework to guide the coordination and implementation of adaptation initiatives through a participatory approach, and to build synergies with other relevant environment and development programmes. NAPA presents priority projects to address the urgent and immediate needs and concerns of people at the grassroots level for adaptation to the adverse effects of climate change in key sectors such as agriculture, water resources, coastal zone and human health.

67. The objectives of the NAPA project are:

- To understand the main characteristics of climate hazards in Cambodia (flood, drought, windstorm, high tide, salt water intrusion and malaria);
- To understand coping mechanisms to climate hazards and climate change at the grassroots level;
- To understand existing programmes and institutional arrangements for addressing climate hazards and climate change;
- To identify and prioritise adaptation activities to climate hazards and climate change.

NAPA was revised in 2012.

3.5. Climate Change Strategic Plan for Water Resources and Meteorology, 2013-2017

68. The Climate Change Strategic Plan for Water Resources and Meteorology is mainly divided into two part, first is climate change strategic plan such for water resources and second is climate change strategic plan for meteorology.

3.5.1. Water Resources

69. The goal of Climate Change Strategic Plan (CCSP) for water resources is to fulfil all climate change adaptation activities in water resources management and development for sustainable water resource use. The objectives of the CCSP for water resources are:

- Protect, manage and use water resources in effective, equitable and sustainable manners, protecting them from the negative impacts of climate change;
- Along with climate change adaptation and mitigation schemes, regulate, modify and subsidize water resource service fees for all water resource development activities;
- Maximize sustainable water resources contributions to poverty reduction, enhanced livelihoods and equitable economic growth;
- Adapt to climate change and mitigate its effects on water resource-based livelihoods;
- Apply Integrated Water Resources Management (IWRM) that allows for holistic planning across sectors, jurisdictions and local government borders for climate change adaptation and mitigation;
- Create stronger community participation in water resource management and development, to address impacts or obtain benefits from climate-change induced opportunities;
- Raise awareness and capacity of institutions, and quality of officials in climate change adaptation and mitigation, to enable sustainable development and management of water resources;
- Ensure environmental protection and conservation of water resources;
- Apply modern sustainable management models adaptive to climate change context;
- Partner with the private sector to develop sustainable financial systems.

3.5.2. Meteorology

70. Climate Change Strategic Plan for Meteorology: The national meteorology services is under responsible for the Department of Meteorology. They responsible for activities such as: observing surface and atmospheric weather conditions and providing weather information necessary for preventing and mitigating natural disasters that can have negative impacts on human societies, communities and socio-economic development.

71. The goal of the climate change strategic plan for meteorology is:

Goal 1: To become a national organization with accountability and responsibility in providing excellent weather forecasting and climate information services in Cambodia.

Goal 2: To be fully coordinated and engaged in a comprehensive study on climate change impacts, as well as climate change responsible measures for the public and development of national climatic information systems for agricultural activities.

The objectives of the department of meteorology are:

- To build a reliable and predictable meteorological service;
- To improve human resource capacity at national and provincial levels to meet the requirements of a high-quality meteorological information service provider;
- To extend climate networking nationally and internationally;
- To set up a national early warning system, and give information related to air pollution.

3.6. Climate Change Action Plans (CCAP) 2014-2018 for various sectors

72. The Climate Change Action Plan (CCAP 2014-2018) is the result of commitment and political support from the royal government of Cambodia. Through this process, 10 concrete climate change action plans (CCAP) were prepared in 2014 by separate Ministries including MAFF, MoWRAM, MoWA, MPWT, MRD, MoH, MoEYS, NCDM, MoInfo, MoT, MLMUPC, MIH, MoME, MoE, and MPTC who have mainstreamed CC issues into their action plans.[7]

3.6.1. Climate Change Action Plan for MPWT (2014-2018)

73. There is much evidence[8] to show that the increasing frequency and intensity of storms and floods are the key threats to transport infrastructure such as road, bridge, railways, waterways, and drainage in vulnerable areas. Two key factors that lead to heavy damage of transport infrastructure are (i) increasing flood intensity, (ii) technical specifications for the design and construction of roads which are inadequate for climate change adaptation.

74. The 2 main strategies and 11 strategic priorities of MPWT to address the adaption and mitigation aspects of transport sector are:

- Promote climate resilience in transport infrastructure

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[7] *"Updating of CCAP in Cambodia" Climate Change Department, MoE February 2016.*

[8] *CCCSP, SCCSP, SNC, NAPA, MoE 2012, MoE-PPCR 2013*

- Develop national road construction and maintenance design standards for national and provincial roads, taking into account climate change impacts
- Repair and rehabilitate existing road infrastructure and ensure effective operation and maintenance system, taking into account climate change impacts
- Capacity building and institutional strengthening for addressing to climate change impacts
- Promote low-carbon consumption for Green House Gas reduction in transport sector
- Raise public awareness on climate change impacts caused by GHGs from transport sector
- Enhance inspection and maintenance of vehicles
- Promote integrated public transport in major cities
- Establish green belts along major roads for climate change mitigation
- Mitigate GHGs for urban transport including mass transit and cycle systems
- Promote environmentally friendly efficient and proven transport technology
- Shift long distance freight movement from trucks to trains
- Enhance traffic management
- Promote climate resilience in transport infrastructure
- Promote low-carbon consumption for Green House Gas reduction in transport sector

3.6.2. Climate Change Action Plan for Agriculture, Forestry and Fisheries (MAFF)

75. This policy was issued in May 2014. The document lays out a plan, investment budget of USD187.5 million, and implementation and monitoring mechanisms aimed towards interventions in ensuring food security for farmers through increase in crop production and agro-industry, better use of appropriate technology, renewable energy, water resources, (climate smart farming systems, post harvest technology, resilient crop varieties, support to agro-industry entrepreneurs and cooperatives for low-carbon production), investments in the rubber sector, increase sustainable livestock production, sustainable forest management (0 balance deforestation by 2020), and fishery resource management.

3.6.3. Climate Change Action Plan for Rural Infrastructure (MRD)

76. This policy was signed in July 2014. The document recognized the tremendous impact climate change has had in Cambodia in recent years, especially the losses incurred in 2011 and 2013. The most affected areas under MRD's responsibility are surface and underground rural water supply, rural roads, and rural socioeconomic and health sectors.

77. The document lays out a plan, investment budget, implementation and monitoring mechanisms aimed towards interventions in further policy development, capacity development, and investments in climate resilient rural infrastructure. These include risk mapping, adaptation options and guidelines for water and sanitation investments around the Tonle Sap.

3.6.4. Climate Change Action Plan for Water Resources and Meteorology (MOWRAM)

78. This policy was signed on 26 May 2014. The document lays out a plan, investment budget of USD303 million, and implementation and monitoring mechanism aimed towards interventions in hydro-meteorology, irrigation works, flood and drought forecasting and protection, sea level rise/ saline intrusion, capacity development of MOWRAM staff, and gender.

3.6.5. Climate Change Strategic Plan (CCSP) for Disaster Management Sector

79. The Strategic Plan on CCA focuses on reducing people's vulnerability to climate change hazards, by strengthening the Disaster Management system and being actively involved in DRR activities, which are the core element of CCA.

80. The Strategic Plan's specific purposes are:

- Promote the relationship between DRR and CCA.
- Promote attention on disaster risk management by focusing on vulnerabilities, poverty and the causes of disasters.
- Show the benefits of promoting capacities in adapting to climate change.
- Promote management of unprecedented events and the uncertainty of climate change.

3.6.6. Climate Change Action Plan (CCAP) for Gender

81. The Objectives of Climate Change Action Plan are to support to the Cambodian Climate Change Strategic Plan (CCCSP) in which indicated in the following:

- Women's participation in climate change policymaking will be increased
- The funding rules for gender and climate change initiatives will be established and made operational through gender-responsive budgeting in the current and upcoming projects/programs/policies (both external and national sources)
- The level of awareness of public policymakers will be increased on the importance of together equality in climate change adaptation and mitigation.
- Women's climate change adaptation and mitigation needs will be met by strategic and catalytic initiative on gender and climate change on priority basic, following the development of criteria, based on the finding of vulnerability and adaptation analyses.
- National capacities are enhanced to plan, implement and monitor gender-integrated climate change adaptation and mitigation initiatives
- Effective mechanism for scaling up the proven experiences on gender and climate change are identified, lessons and best practices of gender and climate change are elicited and analyzed for sharing and learning in national, regional and global forums.

3.6.7. Climate Change Action Plan (CCAP) for Industry and Handicraft

82. There are number of strategic documents which were developed in order to provide guidance to the Industry and Handicraft sectors development in alignment with the sustainable development imperative for the country, including the Climate Change Strategic Plan (CCSP) for Manufacturing Industry and Energy Sectors in 2012, the Cambodia Climate Change Strategic Plan 2014-2023, and the National Strategic Development Plan 2014-2018. This guidance was considered in the

identification of the four strategic priorities which guided the formulation of the sector's response to climate change for the next four year period, namely:

- Promoting green industry for climate resilient low carbon production in Cambodia
- Use of renewable energy and energy diversification including promoting on-site renewable energy captive generation for industrial production processes
- To introduce more path-breaking technologies for low-carbon production industries
- Industrial waste management.

3.6.8. Climate Change Action Plan (CCAP) for Land Management Urban Planning and Construction

83. The main goal of climate change action plan for land management urban planning and construction aims to:

- ensure quality, efficiency, sustainability, and equity of urbanization
- protect the human right of public and private interest in development, conservation and construction
- promote green growth and participating in the climate change adaptation and mitigation as well as natural disaster reduction in the country

3.6.9. Climate Change Action Plan (CCAP) for Tourism

84. The goal of climate change action plan for tourism aims to:

- reduce vulnerability to climate change impacts of people and tourism sector, in particular the most vulnerable and critical systems (natural and societal), and cultural heritage.
- Shifting towards a green development path by promoting low-carbon development and technologies;
- promote public awareness and participation in climate change response actions in the sector

3.6.10. Climate Change Action Plan (CCAP) for Public Health

85. The goal of climate change action plan for public health is to reduce morbidity, mortality, injuries and health vulnerability to climate variability and extreme weathers.

The objectives of climate change action plan for public health is to:

- improve health care infrastructure and capacity of health personnel to cope with vector-borne and water-borne diseases in the context of climate change
- enhance emergency preparedness and response to cope with extreme weathers and climate change related disasters.
- improve knowledge and research capacity on health impacts and vulnerability to climate change as an information base for mainstreaming climate change in the health strategic planning of MoH and other sector planning.

3.6.11. Climate Change Action Plan (CCAP) for Mines and Energy

86. There are six strategic objectives in the Climate Change Strategic Plan for Manufacturing Industry and Energy published in 2012 by former Ministry of Industry, Mines and Energy (MIME).

Four of these are related with industry sector, and two are related with energy sector. Base on the needs and discussions during the development of the Climate Change Action Plan 2016 - 2018, there are two additional strategies have been added. The four strategies are as the following:

- Policy Development in Energy Sector to meet SE4ALL target for Cambodia
- Promote the energy infrastructures to be climate proof or climate resilient
- Implementation of the GHG emission management approach for the energy sector
- Improve capacities, knowledge and awareness for climate change response

3.6.12. Climate Change Action Plan (CCAP) for Education

87. Based on the priority issue, the following education sector climate change strategies have been identified such as:

- To improve education policy and planning for building resilience capacity to response to climate change issues
- To improve education quality on climate change subjects for formal education
- To promote awareness raising and mainstreaming climate change in non-formal education
- To promote green concepts and climate change-proofing of schools, universities and education facilities

3.6.13. Climate Change Strategic Plan (CCSP) for Manufacturing and Energy

88. Ministerial Technical Team for the development of CCSP for manufacturing and energy sectors has set the goals and objectives as follows:

- Strengthen the capacity of related institutional and human resource development both government and private sectors
- To foster and support equipment facilities and materials in order to facilitate for the implementation of strategic plan
- Establish and strengthen communication and sharing system to stakeholders and vulnerable target groups
- Identify Hot-Spot and gas house emission in manufacturing industry and energy which caused the climate change
- Develop climate change foundation for ensuring long-term substantiality implementation
- Transfer the knowledge, experience and technology in green industry and energy by corporation projects and programs from national and international partners for development
- Create information and data system of source and level of impact related to climate change
- To foster and encourage the researcher and technology creator who will support in preventing and reduction the climate change
- To foster and encourage the private sectors participation and vulnerable groups and gender main streaming into climate change
- To motivate and encourage the establishment of research and development (R & D) institutions in place which support the two sectors sound green

- To evaluate and gap analysis the existing legal(s) aspect and guidelines in order that the climate change of two sectors will be integrated consolidated into the new regulation and technical guidelines establishment
- To make the request for new preparing and establishment law, sub-decree ministerial notices, technical norm and guidelines related to climate change of the two sectors and long term legal support for the implementation
- Establish and implement the legislation and regulation included technical standard in green industry and energy

3.7. National Strategic Development Plan (NSDP) 2014-2018

89. NSDP 2014-2018 has addressed climate change in national development planning particularly on Environmental Quality Management. MOE has undertaken measures to strengthen waste management at source and at final dumpsites to control environmental pollution. Large-scale investments are being made in urban waste recycling, waste management and strengthening sewage management at the sub-national levels by setting up wastewater treatment plants in the provinces of Battambang, Preah Sihanouk, Siem Reap, the coastal provinces, and provinces surrounding the Tonle Sap Lake[9].

90. The National Strategic Development Plan (NSDP) emphasizes that 'to effectively deal with the implications of climate change, the capacity of RGC institutions needs to be strengthened to identify and develop a strategy to deal with the anticipated impact of the climate change, and strengthen disaster management capabilities'.

3.8. Cambodia Climate Change Strategic Plan (CCCSP) 2014-2023

91. The Cambodia Climate Change Strategic Plan (CCCSP) 2014-2023 is designed to ensure strategic cohesion to address a wide range of climate change issues concerning adaptation, GHG mitigation, and low-carbon development. CCCSP is the first ever comprehensive national policy document responding to climate change issues launched in November 2013.

92. In May 2015, as part of the Ministry of Environment's structural reform, the Department of Climate Change (DCC) moved under the National Council for Sustainable Development-General Secretariat (GSSD) with a mandate to promote sustainable development aimed at ensuring economic, environmental, social and cultural balance within the Kingdom of Cambodia.

93. The vision, mission and goals of the CCCSP were formulated based on the analysis of institutional capacity, observed climate change impacts and climate change projections.

Vision: Cambodia develops towards a green, low-carbon, climate-resilient, equitable, sustainable and knowledge-based society.

Mission: Creating a national framework for engaging the public, private sector, civil society organizations and development partners in a participatory process for responding to climate change to support sustainable development.

Goals:

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[9] *NSDP 2014-2018*

- Reducing vulnerability to climate change impacts of people, in particular the most vulnerable, and critical systems (natural and societal);
- Shifting towards a green development path by promoting low-carbon development and technologies;
- Promoting public awareness and participation in climate change response actions.

94. To achieve the vision, mission and goals, the Royal Government of Cambodia (RGC) has identified eight strategic objectives:

1. Promote climate resilience through improving food, water and energy security;
2. Reduce sectoral, regional, gender vulnerability and health risks to climate change impacts;
3. Ensure climate resilience of critical ecosystems (Tonle Sap Lake, Mekong River, coastal ecosystems, highlands, etc.), biodiversity, protected areas and cultural heritage sites;
4. Promote low-carbon planning and technologies to support sustainable development;
5. Improve capacities, knowledge and awareness for climate change responses;
6. Promote adaptive social protection and participatory approaches in reducing loss and damage due to climate change;
7. Strengthen institutions and coordination frameworks for national climate change responses;
8. Strengthen collaboration and active participation in regional and global climate change processes.

The CCCSP 2014 – 2023 has set out a number of actions structured into three phases of implementation.

In the immediate term (2013 – 2014): The focus of this phase is on putting in place institutional and financial arrangements for the implementation of the CCCSP, development of national monitoring and evaluation (M&E) frameworks and indicators, and development of climate change action plans (2014 – 2018) by line ministries.

In the medium term (2014 – 2018): This phase will continue to support the implementation of what was planned in Phase 1, with expansion to cover other activities such as accreditation of the Adaptation Fund and Green Climate Fund, research and knowledge management, capacity development, mainstreaming of climate change across sectors at different levels, operation of M&E and data management systems, and launching some high priority projects/programmes in key sectors identified in the Climate Change Action Plans. Initial priority would be given to adaptation activities but gradually GHG mitigation activities will be included. The RGC may undertake a review and revision of the CCCSP 2014 – 2023 building on the lessons learned in Phases 1 and 2.

In the long term (2019 – 2023): The focus of this phase will be on research and learning, but its main objective will be to scale up success cases and to continue mainstreaming climate change into national and sub-national programmes. This will involve an increased use of budget support for national programmes, including funding climate change responses through subnational administrations.

4. CLIMATE CHANGE SCIENCE

4.1. IPCC

95. The Intergovernmental Panel on Climate Change (IPCC) is a U.N. scientific body who produce a series of international assessment reports on the current state of climate change knowledge. The IPCC has facilitated comparison of General Circulation Models by suggesting standard future CO_2 scenarios and standard input data such as temperature, rainfall, wind speed etc. GCMs are constantly being updated and results from each new model are compared to the outputs from all of the others. The IPCC carries out an inter-comparison of General Circulation Model results.

4.2. Developing Appropriate Climate Change Scenarios

96. Climate projections are representations of the responses of the climate system to greenhouse gas (GHG) emissions or atmospheric GHG concentrations. They are typically based on general circulation model[10] (GCM) simulations. Climate change projections can be useful in determining how climate variables, such as temperature and precipitation, may change in the future under various assumptions about GHG emissions.

97. However, projections based on climate model outputs are limited by the imperfect representation of the climate system within such models and by uncertainties associated with future GHG emissions among other factors. Therefore, climate projections should not be viewed as forecasts or predictions, but rather as plausible alternative characterizations of future climate conditions. They are helpful in exploring "what-if" questions; they do not aim to provide accurate or definitive predictions of how climate will behave in the future.

There are four generally used climate change scenarios. These are discussed below.

4.3. Future Scenarios

98. Accurately forecasting the future climate is not possible because of uncertainties in the interactions between the oceans, atmosphere and biosphere. As a result GCMs produce a range of modeled future climate situations. These are not attempts to predict the likelihood of what may happen but the consequences of certain concentrations of GHGs. These are called climate scenarios.

99. The IPCC report (AR Number 5 is the latest) uses "Representative Concentrations Pathway (RCP)". These Representative Concentrations Pathway are projections of the change in the balance between incoming and outgoing radiation to the atmosphere. The numbers refer to global energy imbalances, measured in watts per square meter, by the year 2100.

100. RCP 3 (PD) refers to a scenario where CO_2 emissions peak in the near future and then decline. This is optimistic. RCP 8.5 refers to the worst case scenario where emissions continue to rise until 2100 leading to global temperature increases. This is pessimistic. RCP 4.5 and 6.0 are intermediate scenarios.

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[10] *Computer simulations of air mass and ocean current movements for climate change forecasts and weather forecasts*

101. Recent climate change studies use RCPs of 8.5 for extreme CO_2 future concentrations and values of 3.5 or 4.5 to represent low CO_2 future concentrations. In the projections for MPWT the RCP 8.5 is used. Therefore this is a pessimistic scenario and will give worst case conditions. It is designated the “extreme scenario”.

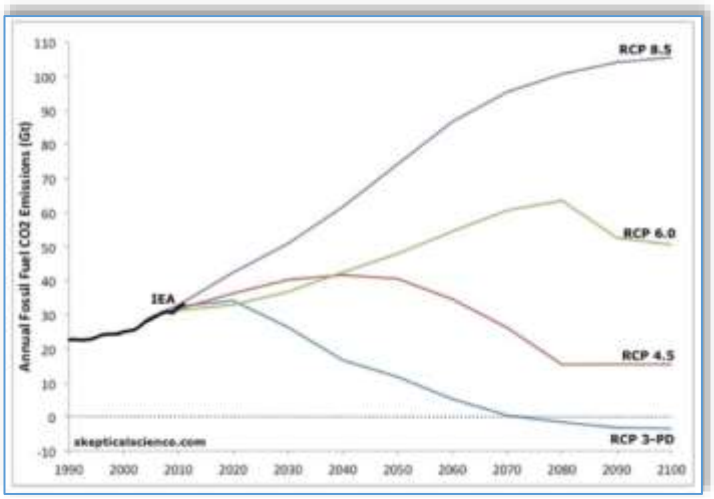


Figure 4-1 RPCs from IPCC AR5 (2011)

4.4. General Circulation Models used in the Region

102. More than 20 different GCMs have been used to model climate change in Cambodia. The suitability can be assessed by comparing modelled results with measured climate data. Models that most accurately predict current monsoon rainfall are the most suitable.

103. While GCMs predict temperature reasonably well the projected extreme precipitation intensities are generally much lower than observed data. The timing of the start and end of the monsoon season are also generally poorly predicted.

104. Rainfall errors are generally between 1.5 to 2.5 mm/day. The worst performing model showed rainfall errors of over 4 mm/day. The most widely used model showed rainfall with errors of less than 1.5 mm/day. This was used in the MPWT project.

4.5. Downscaling General Circulation Model outputs to regional scales

105. Global models are intended for use with large spatial scales and are too coarse to determine local scale climate variations in precipitation. Downscaling climate data generates locally relevant climate data from GCMs. Downscaling obtains regional weather phenomena that are influenced by the local topography, land-sea-contrast, and small-scale atmospheric features such as convection. The CSIRO modeling is the latest and presents downscaling information at the highest resolution.

4.6. Projected Temperature change

106. All these models show warming occurring over Cambodia in the future, with the early studies generally projecting warming of 0.01ºC to 0.03ºC per year, and later models projecting warming of 0.03ºC to 0.06ºC per year. This equates to a warming of 0.35ºC to 2ºC by 2050 and 1ºC to 5ºC by 2100.

4.7. Projected Rainfall Change

107. Climate in Cambodia is traditionally described with reference to two seasons, the wet season, when rain bearing monsoon winds from the southwest predominate and the dry season, when dry northeast monsoon occurs. Climate change could result in changes in the total amount of rain in each season and a change in the onset or end of the wet season. Climate change studies project a shorter wet season in the future with a later start and a longer drier dry season. The results for rainfall change are much more varied than those for temperature.

108. The models project an overall decrease in rainfall during the wet season, an increase at the start of the wet season and an increase in the amount of rain that falls in extreme events. The first points are significant to farmers. This latter point is significant for drainage design.

4.8. Rainfall Intensity

109. Climate change studies have projected an increase in rainfall intensity during rainy days by 2055. A decrease in the total yearly rainfall that is projected for some locations is a result of a decrease in the number of rainy days not a reduction in intensity. The CSIRO's CCAM model projected an increase of daily rainfall of 10 to 20mm.

110. While climate models are run at intervals of 1 hour or less the outputs that are generated are at the scale of 1 day. Predictions of rainfall intensity in terms of mm per hour may under estimate maximum rainfall intensity. As a guide, in tropical conditions, hourly rain fall can be assumed to be 20-40% of daily rainfall.

5. CURRENT AND PROJECTED METEOROLOGICAL DATA

5.1. Data Availability

111. The Department of Meteorology (DoM) of MOWRAM has 38 meteorological stations that record rainfall, 23 that record evaporation, and 14 stations that record wind speed. The MRC maintains 12 stations in Cambodia. Key stations send data daily to DoM for weather forecasting. Rainfall, air temperature, wind speed, wind direction and relative humidity are observed by only two main stations at Pochentong and Sihanoukville.

112. Recent studies for MPWT[11] have produced the following data:

- Current 1 day extreme rainfall output for the period 1980 - 2000
- Projected 1 day extreme rainfall for the two decade period centered on 2055 for RCP 8.5
- Current 5 day extreme rainfall output for the period 1980 - 2000
- Projected 5 day extreme rainfall for the two decade period centered on 2055 for RCP 8.5

The projections simulated the extreme event RCP 8.5.

5.2. Current 1 Day Extreme Rainfall

113. The current 1 day extreme rainfall represents the maximum rainfall output by the models for a 20 year period centered on 1990. The distribution of 1 day extreme rainfall reflects the spatial distribution of annual rainfall with high values of around 200mm in the mountainous region near the coast, in Mondul Kiri and in the far north east. Smaller 1 day extreme events of 100 – 145 mm occur in the central flat lands and hilly regions in the north. The lowest values are around Tonle Sap.

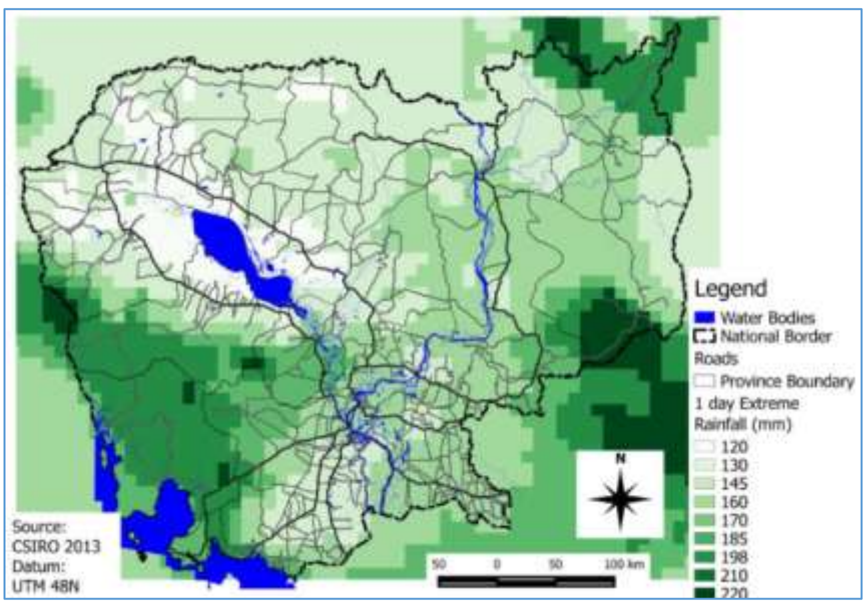


Figure 5-1 Current 1 day extreme rainfall from the CCAM model.

[11] *Flood Risk Management Interface Manual, MPWT, September 2015*

5.3. Projected 1 day extreme rainfall for 2055 with RCP of 8.5

114. The projected 1 day extreme rainfall is the average for a 20 year period centered on 2055 using an RCP of 8.5. The projected change in 1 day extreme rainfall is the difference between current and projected 2055 values. The model projects an increase over the coastal mountains and over the hilly regions in the north of the country. There is no change or only a small change for the central flat areas, except for a small area north east of Phnom Penh.

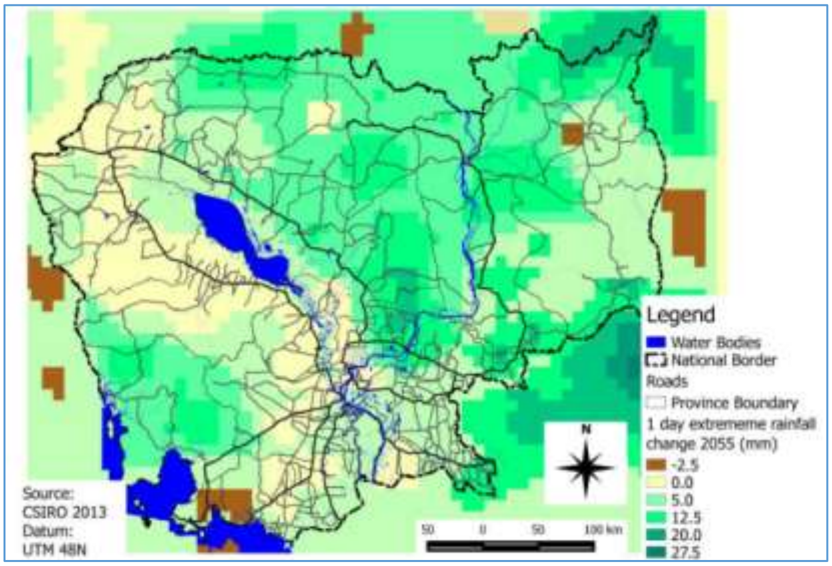


Figure 5-2 Projected change in 1 day extreme rainfall for 2055 (RCP 8.5 from CCAM)

5.4. Current 5 day Extreme Rainfall

115. The 5 day extreme rainfall map is defined as the maximum total rainfall recorded over 5 days for a 20 year interval centered on 1990. The distribution of 5 day extreme rainfall reflects the spatial distribution of annual rainfall with high values of 300mm or more in the mountainous region near the coast, in Mondul Kiri and in the far north east.

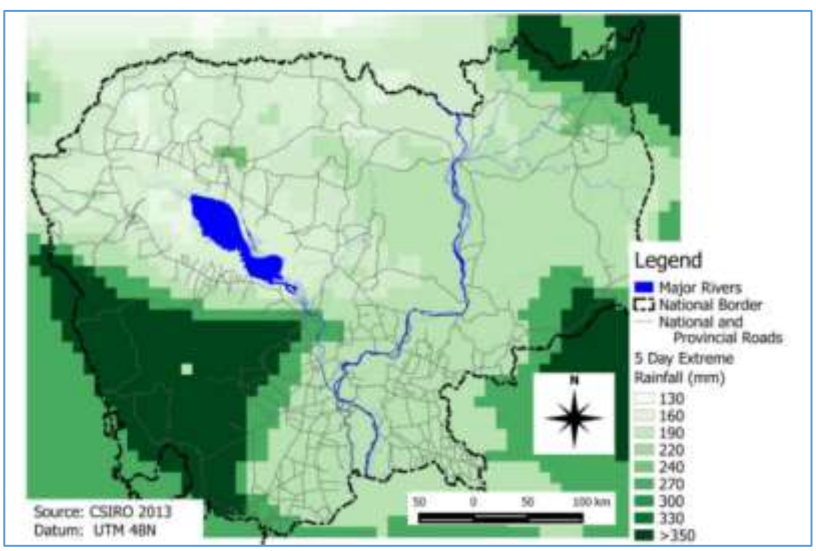


Figure 5-3 Current 5 day extreme rainfall from CCAM

Smaller 5 day extreme events of 150 – 180 mm occur in the central flat lands and hilly regions in the north. The model shows the lowest values around Tonle Sap.

5.5. Projected 5 day extreme rainfall for 2055 with RCP of 8.5

116. The projected 5 day extreme rainfall is the average for a 20 year period centered on 2055 using an RCP of 8.5. The projected change in 5 day extreme rainfall is the difference between current and projected 2055 values. The model projects a small increase in 5 day extreme rainfall over the coastal and other high mountains but a more pronounced increase of 16-20 mm per day for the hilly regions to the west of the Mekong in the north of the country. Little change or a slight decrease is projected to occur in the lower hilly areas east of the Mekong. The most pronounced change is a projected decrease of 5 day precipitation of over 17 mm per day for the flat areas south and southwest of Tonle Sap. It is projected to increase in Svay Rieng.

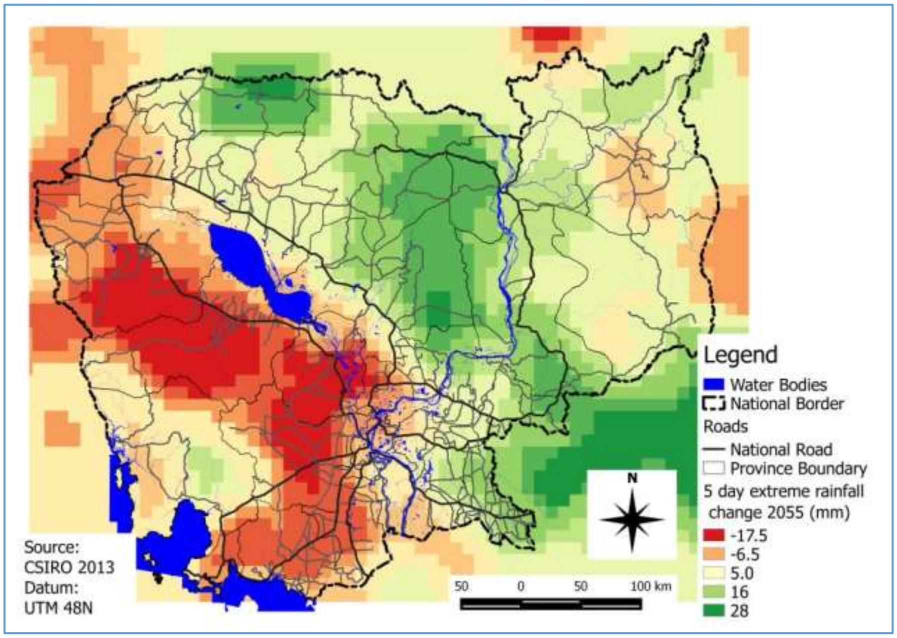


Figure 5-4 Projected change in 5 day extreme rainfall for 2055 (RCP 8.5)

5.6. Changes to 1-day Precipitation

117. The increases are modest for the 2030 projection (6 to 8%) and the 2050 projection (9 to 10%) but larger for the 2070 projection (28 to 34%).

5.7. Changes to 5-day Precipitation

118. The 5-day maximum precipitation increases for all future time frames; from 9% to 14% for the 2030 projection, from 16% to 20% for the 2050 projection and 29% to 38% for the 2070 projection. The 5-day duration is likely to correspond to the critical flood duration for some of the larger river basins.

5.8. Tonle Sap Basin

119. An ADB project with MOWRAM produced a database of climate change parameters to help predict the ranges of climate change.[12] The climate change parameters projected are temperature – average, maximum and minimum daily temperatures; and rainfall - monthly averages and daily maxima. These can be used to develop further parameters which are more directly useful for understanding the risks of flood and drought, such as frequency of storm events and hydrological flows in the river, frequency of dry periods in the rainy season and evaporation rates and soil moisture content.

120. Results were produced for five hydrological basins. The results for the changes projected under climate change scenario A1B for different basin areas of Cambodia are shown in Table 5-1. The Tonle Sap Basin is shown in Column 4. This basin covers the whole of Tonle Sap and also includes Pursat and Kampong Chhnang.

121. The projections for the Tonle Sap Basin show that:

- Annual rainfall is likely to increase by 59 mm to 1,616 mm
- The number of wet days will decrease by nearly 10 days per year to 155 days
- The 5-day rainfall will increase by 6.65 mm to 53.23 mm
- The daily rainfall intensity is likely to increase by 0.75 mm/day to 10.51 mm/day
- The wet day rainfall % is likely to increase by 6.05% to 29.36%
- The wet days % is likely to increase by 3.11% to 12.65%
- The daily rainfall intensity recurrence interval will be 7.76
- The consecutive dry days will increase by 6.64 days to 58.9 days
- The number of occurrences of dry periods will decrease by 0.39 to 8.44
- The hot day temperature is likely to increase by 1.74 deg C to 41.97oC
- Heat wave duration index will increase by 4.81 days to 5.00 days

[12] *Water Resources Management Sector Development Program TA-7610-CAM, EGIS International, 2014.*

Table 5-1 Baseline and mid-century Climate Change Indicators for Basin Planning Groups

No.	Climate Change Indicator	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5
		Coastal Zone	3S (SA 7C)	Mekong Upstream (SA6+8C)	Tonle Sap (SA 9C)	Delta (SA 10C)
A	Rainfall (mm)					
A1	Annual Rainfall (mm)					
	- Annual Rainfall Baseline	2,689	2,131	1,902	1,557	1,708
	- Annual Rainfall Project A1B	2,801	2,234	1,986	1,616	1,770
	- Annual Rainfall Change A1B	112	104	84	59	62
A2	Number of wet days (days)					
	- Number of wet days Baseline	175	164	161	164	165
	- Number of wet days Projection A1B	162	158	155	155	155
	- Number of wet days change A1B	-12.9	-6.99	-8.15	-9.80	-9.52
A3	5 Days Rainfall (mm)					
	5 Days Rainfall Baseline	91.95	81.67	63.19	46.58	59.34
	5 Days Rainfall Projection A1B	105.04	92.61	71.98	53.23	65.71
	5 Days Rainfall Change A1B	13.09	10.94	8.79	6.65	6.37
A4	Daily Rainfall Intensity (mm/day)					
	Daily Rainfall Intensity Baseline	17.32	14.39	12.81	10.51	11.56
	Daily Rainfall Intensity Projection A1B	18.16	15.74	13.88	11.26	12.08
	Daily Rainfall Intensity Change A1B	0.84	1.35	1.07	0.75	0.52
A5	Wet Day Rainfall (percent)					
	Wet Day Rainfall Baseline	25.03	26.11	24.95	23.32	25.19
	Wet Day Rainfall Projection A1B	31.02	31.95	30.76	29.36	31.08
	Wet Day Rainfall Change A1B	5.99	5.84	5.81	6.04	5.89
A6	Wet Days (percentage)					
	Wet Days Baseline	9.56	9.51	9.53	9.54	9.54
	Wet Days Projection A1B	12.54	12.56	12.53	12.65	12.41
	Wet Days Change A1B	2.98	3.05	3.00	3.11	2.87
A7	Daily Rainfall Intensity Occurrence Interval	3.42	3.09	4.09	7.76	4.27
B	Dry Days (days)					
B1	Consecutive dry days (days)					
	Consecutive dry days Baseline	47.02	55.6	54.39	52.26	54.75
	Consecutive dry days Projection A1B	53.81	61.16	60.86	58.9	61.54
	Consecutive dry days Change A1B	6.79	5.56	6.47	6.64	6.79
B2	Number of dry periods (number of occurrences)					
	Number of dry period Baseline	8.90	8.89	8.74	8.83	9.16
	Number of dry period Projection A1B	8.56	8.60	8.42	8.44	8.8
	Number of dry period Change A2B	-0.34	-0.29	-0.32	-0.39	-0.36
C	Temperature (degree C)					
C1	Hot day temperature (degree C)					
	Hot day temperature Baseline	36.83	37.78	39.5	40.22	37.98
	Hot day temperature Projection A1B	38.37	39.79	41.45	41.97	39.72
	Hot day temperature Change A1B	1.54	2.01	1.95	1.75	1.74
C2	Hottest temperature (degree C)					
	Hottest temperature Baseline	36.83	37.78	39.50	40.22	37.98
	Hottest temperature Projection A1B	38.37	39.79	41.45	41.97	39.72
	Hottest temperature Change A1B	1.54	2.01	1.95	1.75	1.74
C3	Heat wave duration (days)					

	Heat wave duration Baseline	0.06	0.24	0.19	0.19	0.05
	Heat wave duration Projection A1B	3.82	7.02	5.59	5.00	3.28
	Heat wave duration Change A1B	3.76	6.78	5.40	4.81	3.23

6. DRAINAGE DESIGN

6.1. Return Period for Drainage Design

122. Drainage design is based upon a statistical analysis of historical rainfall. From this design, return periods are developed to estimate the likely recurrence interval between rainfall events and levels of flooding. Return periods are statistical measurements denoting the average recurrence interval over an extended period of time.

123. For drainage and flood control the return period is given in years, such that a drainage system might be designed for a 20 year flood return period. This implies that there is a probability of the drainage system's capacity not being able to deal with floods every 20 years. However, it is a purely statistical calculation and it is possible that the stormwater system's capacity could be overcome during storms in two consecutive years, or even twice in the same year.

124. In order to size the drains a design return period has to be selected. For higher return periods the drainage system has larger diameter pipes and so is more expensive. As return periods are based on historical data which projects into the future there is a need to consider climate change as more intensive rainfall will increase flows.

6.2. Climate Resilient Design and Uncertainty

125. Drainage design is normally based on 1 hour rainfall. For Cambodia this is typically a rainfall intensity of 30 mm per hour for a 1 in 2 year event. This can be increased to 40mm per hour to accommodate the more intense rainfall expected from climate change and be used for drain design. This is the figure for a 1 in 5 year event. This may be too small. The climate change projections indicate a small change in **annual** rainfall, being around +8% in the wet season but it is the **short term** intensity of rainfall that is important in drainage design.

126. In a recent peer reviewed paper it was stated that for short duration rain fall the intensity of the rain fall may increase by 10% for every increase in temperature by 1^{o}C.[13] The projections for Tonle Sap basin show a possible temperature increase of +3.5^{o}C although the recent Paris Conference December 2016 committed to maintaining global temperatures below 2^{o}C. Taking 2^{o}C as a maximum would indicate an increase of intensity of 20% in rainfall. This would approximate to a 1 in 10 year event. In order to incorporate climate change resilience into the drainage system it may be better to design to a 1 in 10 year event.

127. There are three different and contrary factors to consider:

- more rain in the Tonle Sap basin due to climate change
- more flow in the Mekong river due to upstream earlier snow melt
- less flow in the Mekong river due to upstream hydro dams

All of these add to uncertainty in choosing parameters for design.

[13] *"Sensitivity of tropical precipitation extremes to climate change." Paul A. O'Gorman, Massachusetts Institute of Technology, Nature Geoscience J Vol 5, October 2012*

7. ASSESSING CLIMATE CHANGE RISKS

7.1. ADB's Climate Risk Management Framework

128. The climate risk management approach of the Asian Development Bank (ADB) aims to reduce risks resulting from climate change to investment projects. ADB's framework identifies climate change risks to project performance in the early stages of project development, and incorporates adaptation measures in the design of projects at risk. ADB climate risk management framework comprises the following steps:

i. context-sensitive climate risk screening at the concept development stage to identify projects that may be at medium or high risk;
ii. climate change risk and vulnerability assessment during preparation of projects at risk;
iii. technical and economic evaluation of adaptation options;
iv. identification of adaptation options in project design; and
v. monitoring and reporting of the level of risk and climate-proofing measures.

7.2. Climate Risk Screening

129. All ADB projects are screened for climate risks. An initial screening identifies medium or high risks which need further screening. Risks considered are those resulting from temperature increase, precipitation change, wind speed change, sea level rise, solar radiation change, water availability, flooding, tropical storms, wildfire and landslide.

7.3. Climate Risk and Vulnerability Assessment

130. A detailed climate risk and vulnerability assessment is carried out for projects classified as medium or high risk during project preparation. The assessment aims to quantify risks and identify adaptation options that can be integrated into the project design. The level of technical rigor of the assessment depends on the project complexity and availability of climate data and information for the project area. It can range from a simple desk analysis to a complex assessment based on custom climate projections to enable a more detailed assessment. This was the approach adopted in this study with site specific climate change projections being produced.

7.4. Technical and Economic Evaluation of Adaptation Options

131. Based on the climate risk and vulnerabilities assessed, adaptation options are identified and evaluated on the basis of their technical feasibility and economic viability. Technical feasibility evaluates whether proposed engineering and non engineering measures can be implemented with available skills, equipment, and other local factors such as geography, governance, and capacity.

132. The economic analysis involves estimating and comparing the cost and benefits of the project based on two different scenarios: (i) the project under climate change without adaptation measures, and (ii) the project under climate change with adaptation measures. It aims to identify which adaptation option yields the highest net benefit. It also aims to estimate the incremental cost of adaptation as the cost of project activities aimed at addressing specific climate vulnerabilities. Recognizing that investing in adaptation measures may be costly and that future benefits may be uncertain, the economic analysis can also point to the best timing for investing in

adaptation. It is possible that interventions can be scheduled for a later time without compromising effectiveness of options. These can be classified as "No Regrets Decisions".

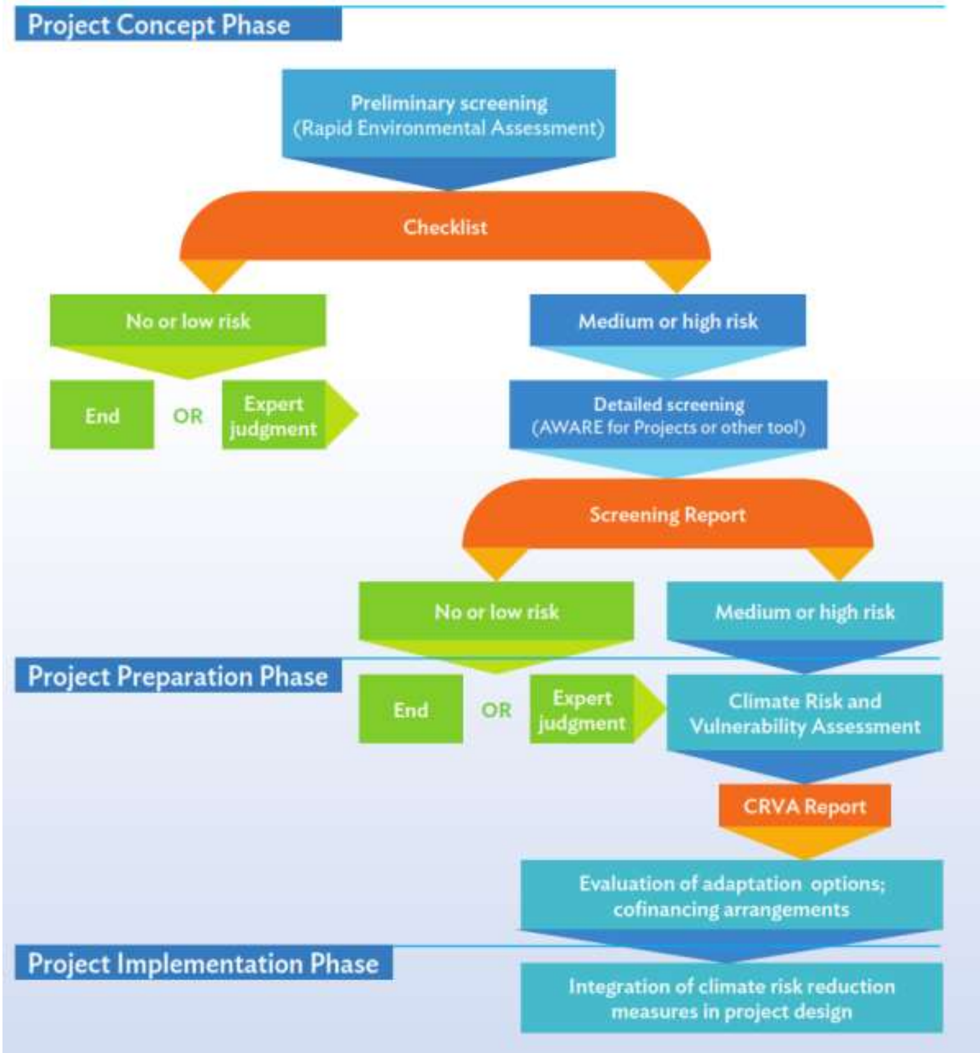


Figure 7-1 Risk Assessment Process

133. Decision makers may elect to invest minimally at the early stages of a project but ensure that the project can be climate proofed in the future if and when circumstances indicate this to be a better option than not climate proofing. This decision ensures that the project is “ready” for climate proofing, if and when required. This is known as "climate readiness" and avoids the foreclosure of climate-proofing options and preserves flexibility to improve climate resilience as climate change is actually observed as opposed to projected.

7.5. Identification of Adaptation Options

134. The most viable adaptation options or climate proofing measures are identified in consultation with the executing agencies or project sponsors, and are integrated in the project design. There is no standardized approach to climate proofing. In some cases, climate proofing is essential to ensure the project is not negatively affected by climate change. In other cases, the lifetime of the project is such that climate proofing is not a viable option or climate readiness is a

more appropriate approach. Climate proofing may involve adjusting engineering design such as increasing drainage capacity of water supply systems, elevating roads in areas particularly at risk from flooding, or ecosystem-based adaptation measures such as revegetation of unstable slopes.

7.6. Climate Proofing Projects

135. The process of climate proofing investment projects aims both at assessing the climate risk to a project’s future costs and benefits and at undertaking a technical and economic analysis of options to alleviate or mitigate those risks. Accounting for climate change at the outset of the project cycle does not imply that climate-proofing measures with large and costly investments need to be put in place as project implementation is initiated. It does imply, however, that decisions about project design and the adoption and timing of climate-proofing measures be informed with the possible impacts of climate change in the initial phases of the project cycle and that decisions of an irreversible nature be avoided. This is the essence of "No Regrets" Decisions.

7.7. AWARE for Projects

136. AWARE for Projects is an online tool used by ADB project teams to screen projects for climate risks. The tool uses data from 16 general circulation models, as well as databases on temperature increase, wildfire, permafrost, sea ice, water availability, precipitation change, flooding, snow loading, tropical storms, and landslides. For each project screened, the tool generates an overall climate risk ranking of low, medium, or high; key risk areas; and narratives on potential impacts and adaptive measures to guide subsequent activities. The following diagram gives an example of climate risk for a wastewater projects.

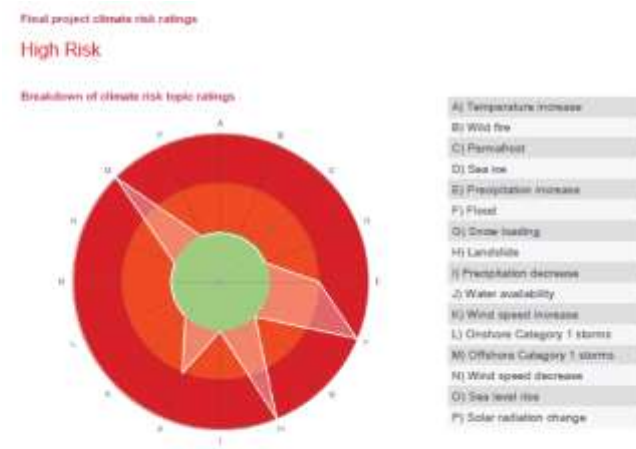


Figure 7-2 Example of AWARE climate risk ratings for wastewater subproject

137. The AWARE is intended as a "first step" to flag potential issues that are subsequently checked in relation to project context and components. Site visits and analysis of further data are needed to confirm concurrence with the AWARE findings.

8. POTENTIAL IMPACTS OF CLIMATE CHANGE ON WASTE MANAGEMENT AND HEALTH

8.1. Changes in Temperatures

138. Changes in ambient air and water temperatures can cause the following effects:

- In some instances, warmer temperatures may improve biochemical treatment processes, particularly in cold regions or seasons; in other instances (particularly in warm areas), the efficiency of these processes may be reduced if critical thresholds are exceeded.
- Temperature increases may result in a reduction of surface water availability by decreasing runoff and increasing evaporation from lakes and reservoirs.
- Higher water temperatures will decrease dissolved oxygen capacity, potentially leading to hypoxia, toxic algae growth, and proliferation of waterborne diseases.
- Higher temperatures may increase agricultural water demand due to decreasing soil moisture and increasing evapotranspiration demand.
- Increases in periods of intense heat may result in higher water demands for domestic and industrial uses.

8.2. Changes in Precipitation

139. Changes in precipitation can cause the following effects :

- Reduced precipitation levels can decrease the availability of both surface water and groundwater.
- Increased precipitation intensity and flooding can overwhelm existing drainage infrastructure.
- High-intensity precipitation may increase erosion; larger sediment loads may result in more rapid sedimentation of storage reservoirs, reducing storage capacity.
- Changes in the amount of rainfall may affect the performance and operation of water systems; increases in precipitation may put pressure on urban drainage systems while sewerage systems may become more difficult to operate and maintain if precipitation levels and discharge decline.
- Long-term rainfall increases may elevate groundwater levels, decreasing the efficiency of natural purification processes and increasing the risk of infectious disease and exposure to toxic chemicals.

8.3. Changes in Extreme Weather Events

140. Changes in frequency, duration, severity, and distribution of extreme weather events can affect sanitation services and infrastructure in the following manner :

- The structural integrity of basic water infrastructure may deteriorate due to floods and periods of intense heat and cold.
- Increases in the intensity of floods may result in the contamination of water sources and may increase the incidence of waterborne and water-related diseases.
- Increases in the frequency and intensity of droughts will cause reduced surface discharge and falling groundwater tables, which can lead to increasing source water pollution and to the drying up of wells, extending the distances that must be travelled to collect water.

8.4. Waste Management

141. There are no specific targets in the NSDP 2014-2018 for treatment and safe disposal of wastewater and/or septage. In terms of the institutional framework, at national ministerial level there is not yet a consensus how sanitation/waste water services are best managed, regulated and delivered by local service providers, such as through either municipal departments, provincial departments of MPWT or through a combined utility water and wastewater approach.

142. JICA provided extensive support for drainage and flood protection infrastructure in Phnom Penh and is now developing a master plan combining drainage, flood protection and sanitation. ADB is pipelining sanitation investments in other cities. Other cities have not yet developed city-wide sanitation plans and will require intensive external support to do so.

143. Faecal sludge management solutions are not reflected in the NSDP 2014-2018 or in priority agenda of MPWT. Communications programs that aim to incentivize households to regularly empty their septic tanks/pits are not yet executed neither are there incentives for the private sector to expand such services and comply with safe disposal rules. Due to the early stages of development of the urban sanitation sector, opportunities for private sector participation in the operation and maintenance of wastewater treatment plants are premature.

144. From all wastewater collected it is estimated that around 40% is treated[14]. While discharge standards exist, compliance is not subject to ongoing third party monitoring, though the Ministry of Environment is said to conduct annual checks. The targets for Water Supply and Sanitation for 2025 are given below.[15]

Table 8-1 Targets for Water Supply and Sanitation 2025

	Status		Targets		
	2012 (NSDP)[a]	2012 (JMP)[b]	2015 (CMDG)[c]	2018 (NSDP)[a]	2025[d] (RWSSH Strategy/SDA target)
Water supply national	51%[a]	71%	-		100%
Rural	47%	66%	50%	60%	100%
Urban	69%	94%	80%	85%	100%
Sanitation national	36%[a]	37%	-		100%
Rural	25%	25%	30%	65%	100%
Urban	>80%	82%	74%	>80%	100%

145. There are many potential impacts of climate change on water supply and sanitation related projects.[16] These are discussed below.

[14] *NSDP 2014-2018*

[15] *NSDP 2014-2018*

[16] *Guidelines For Climate Proofing Investment in the Water Sector : Water Supply And Sanitation, ADB 2016*

8.5. Adaptation Measures

146. Various adaptation measures are available such as the following:

- Water supply can be protected against increasing variability of seasonal and annual precipitation and runoff by building additional water storage infrastructure, such as reservoirs or storage tanks, to provide buffers.
- Adjusting infrastructure designs and introducing flexibility in water systems operations can build resilience to changing climatic conditions such as changes in the seasonality of precipitation and changes in flood return periods.
- Diversifying water supply sources—including conjunctive use of surface and groundwater, reuse and recycling, and use of household-level water sources such as roof water harvesting—can mitigate the impacts of weather-related disruptions on any given component of the water supply system.
- Flood protection infrastructure can help prevent contamination of water supply sources and treatment works. In some cases, water storage can also contribute to downstream flood control.
- Increasing coverage of community water supply infrastructure can improve dependability under changing climatic conditions.
- Green roofs, street trees, wetlands, and porous paving can reduce the volume of stormwater runoff and decrease pressure on wastewater treatment facilities.
- The preservation of riparian wetlands upstream of water users can improve water quality and quantity and provide flood protection at times of high-intensity or long-duration precipitation.
- Separation of stormwater and sanitary sewers can minimize the risk of overwhelming collection systems and water treatment facilities in times of heavy precipitation.
- Integrated water resources management within river basins can improve the allocation and management of scarce water resources in the context of climate change.
- Promoting the efficient use of water through programs, incentives, and technologies for water conservation and water recycling can help reduce water demand.
- In coastal areas, water utilities can utilize desalination of seawater or brackish water to supplement insufficient freshwater resources.
- A properly prepared disaster response strategy can reduce the negative effects of water service disruptions, particularly to critical services such as sanitation and domestic water supply.
- Ensuring that water authorities and stakeholders are equipped with adequate data, information, and skills will help them to respond to the impacts of climate change.

9. MPWT FRMI

9.1. MPWT FRMI - Flood Risk Management Interface Software

147. Cambodia is one of the pilot countries participating in the Pilot Program for Climate Resilience (PPCR). The PPCR provides incentives for scaled-up action and transformational change in integrating consideration of climate risks and resilience in national development planning, consistent with poverty reduction and sustainable development goals.

148. The improvement of access to knowledge, to its dissemination and its conservation was addressed by the development within MPWT of a knowledge management tool called Flood risk management interface (FRMI). This software provides easy access to information about floods and roads, as well as flood risk maps developed under the CR-PRIP.

149. A copy of the Flood Risk Management Interface (FRMI) Version 1.2 was obtained from MPWT. MPWT recommends that it be used in the Climate Risk and Vulnerability Analysis study (CRVA). FRMI simulates flood risk projections for Cambodia under RCP8.5 for 2050.

9.2. FRMI Methodology

150. The FRMI methodology consists of identifying of road links and parameters based on topographical analysis of road physical parameters and assessing the flooding types that they are exposed to. The topographical analysis is derived from Shuttle Radar Topographic Mission (SRTM) data available from public internet sources. Topographical data is based on remote sensing not physical site measurements.

151. Road segments from the National and provincial road network are sourced from MPWT RAMS data and catchment areas. Other geographical parameters are then calculated for each road segment. Road resilience is derived from its condition level as provided by the RAMS system. Finally, flood impact or damage risk assessments are carried out for four specific types of flood and mapped.

9.3. SRTM Accuracy

152. The approximate accuracy of a road location and elevation can be obtained from SRTM but that accuracy is in principle limited by the size of the grid utilized. The SRTM data used in the project was retrieved from a 90 m grid or cell. For such a grid the absolute accuracy of SRTM data ranges from 10 to 20 meters in all directions.

153. The distance of 90 m means that break points, steep slopes or vertical drops would not be traced accurately for countries with significant mountainous terrain, as all slopes are interpolated from point measurements. In low variability terrains like flood plains in Cambodia the overall error in elevation is relatively low. Errors factors of 1 to 2 meters have been established by comparing SRTM data with measured and benchmarked elevations from roads.

9.4. Road Catchment Area vs. River Catchment Area Method

154. The FRMI uses a road catchment area method rather than a river catchment area method, mainly for effectiveness purpose related to data management and better correlation to road impacts. It is possible to calculate every major river catchment area in the whole country and to organize the gained information according to the river flow network. However MPWT data is

orientated towards the road network, not the river network. It is much easier to use the existing road section data base as the main analytical unit and attach flooding values to the individual road sections. Also repair budgets are attached to established road sections, rather than catchment areas or river sections.

9.5. Flood Risk Damage Maps

155. Flood risk damage maps have been produced for various types of floods. The road vulnerability maps present four road risk flooding damage indexes corresponding to different flood types. Another index combines the risk of the four flood type for prioritization purposes. It must be noted that experiencing flooding or being subject to flood risk does not necessarily inflict a lot of damage to every road. The overall equation is:

Flood damage risk = Risk of flood occurrence x Road condition factors

156. The flood risk calculation process starts by evaluating the risk of occurrence of the four types of flood. The main input is the 1 day or 5 day extreme rainfall event, the drainage areas, slope and shape. This leads to the build up intensity next to the road. It then introduces factors to account for the resilience of the road to these floods. Road resilience is assessed in the model through three indicators, the pavement surface roughness, the pavement type and the condition of the drainage structures. The road resilience factors are then applied in terms of the pavement structure and how efficient the drainage system is under extreme rainfall. Four flood indexes are produced which are then combined into one composite index. The flood risk indexes are:

- Flash Flood Index
- Large Drainage Area Index
- Build-up Area Flooding Index
- Low Land Flooding Index
- Combined flood risk index

157. The flow chart for this is shown below.

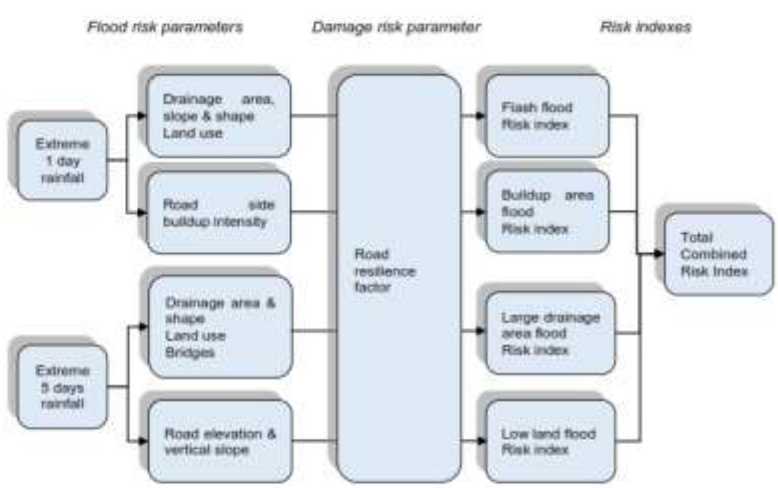


Figure 9-1 Flow Chart for Derivation of Flood Index

158. All these indexes are the basic tools for prioritizing the climate proofing of individual road sections. This is then added the impact of climate change on the flood risk situation. This is projected to the year 2055.

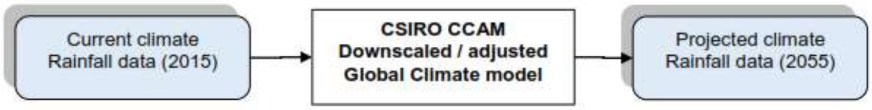


Figure 9-2 Climate Change Analysis

159. A climate change scenario calculation using the projected 2055 rainfall data was carried out and the changes compared to the existing situation. The relevant maps have been produced at the national scale and for all the provinces. The types of maps available are :

- Flood damage risks – current conditions
- Flood damage risks – future conditions
- Flood damage risk changes in time

160. A flood damage risk map shows the road sections associated with four risk levels, ranging from high (red), moderate (orange), low (yellow) to none (green). Maps of the flash flood analysis show that flash flood risks are located in all provinces where there is mountainous terrain. Highest risk areas are in Mondulkiri, Ratanakkiri and Pursat.

161. Large catchment areas high floods risks are distributed all over the country with no specific patterns as urban flood risk areas and lowland flood risk areas are concentrated along the Tonle Sap and the lower Mekong region. This is where most of the population is located and it is an area of low geographical elevations.

9.6. Multiple Flood Vulnerability

162. For each province each road may be at risk from multiple sources of flooding. The analysis was carried out on the basis of road sections so the entire length of any section may not be susceptible to each flood risk factor and the lengths shown can be an over estimation.

9.7. Climate Change Projections

163. The projections are based on current conditions and future values for 2055 under a high CO_2 climate change scenario which is RCP 8.5.

9.8. Appropriateness of FRMI

164. It is acknowledged that FRMI is targeted at road segments. However it does cover the whole of Cambodia and the flood risks considered are generated by overland flow due to flat terrain or flash floods in water courses. Therefore although roads are the main consideration any other structures in the vicinity may be exposed to a similar level of risk.

165. This software is promoted by MPWT and the consultants were advised by MPWT management to utilise it.

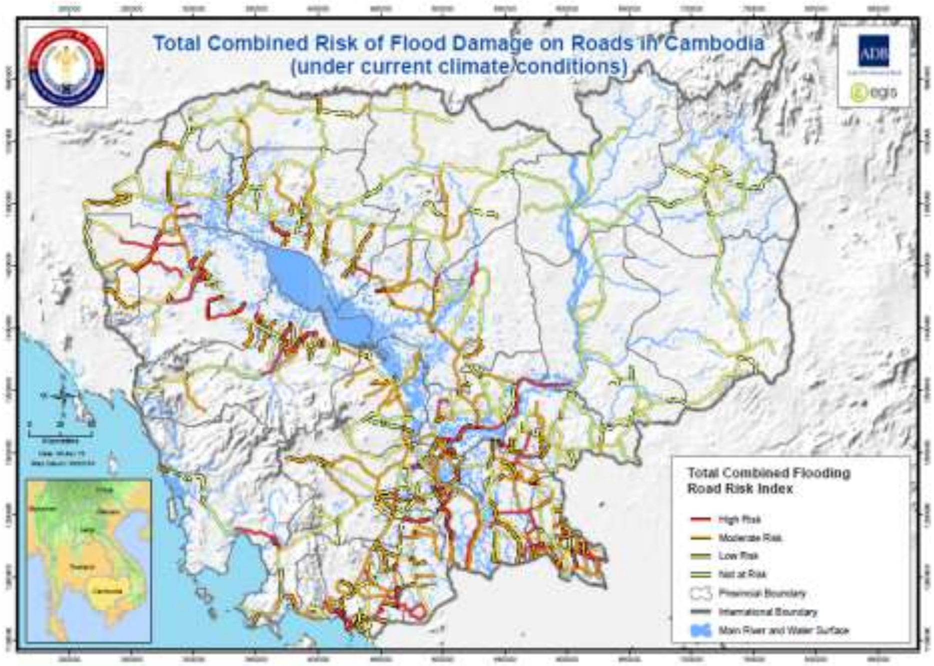


Figure 9-3 National Flood Risk under Current Climate Conditions

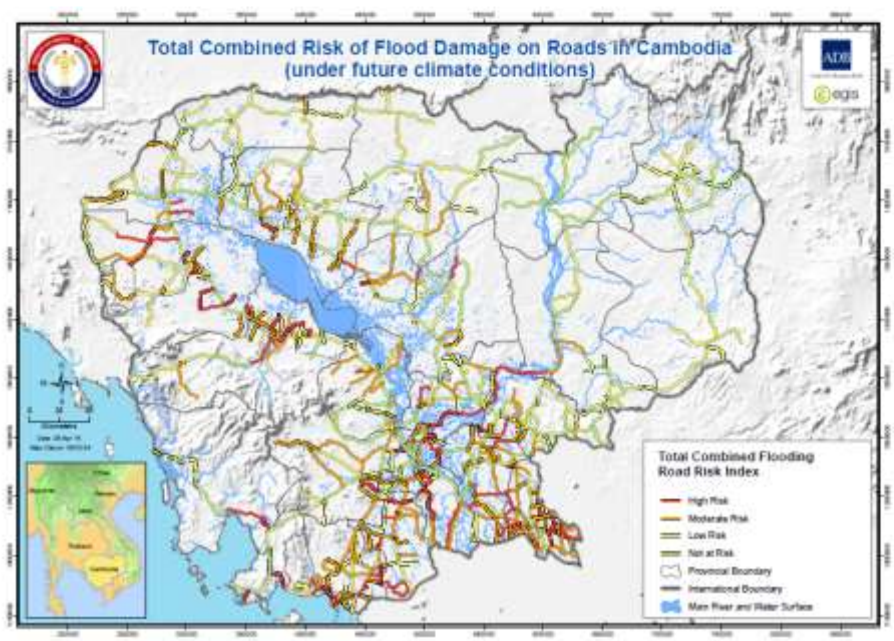


Figure 9-4 National Flood Risk under Future Climate Conditions

166. Both maps indicate an increase in the risk of flood damage to roads in the TLS provinces. This can be taken as indicative of the overall risk of flood to the areas around these roads; this is especially acute for lowland flood damage.

10. SOURCES OF CLIMATE CHANGE PROJECTIONS

10.1. Comparison of Projections

167. There are at least four separate recent climate change projections for the Tonle Sap area. Not all projections contain the same parameters but a comparison can be made.

Table 10-1 Comparison of Climate Change Projections from Various Sources

Parameter	Season	USAID 2013	MOWRAM 2014	Battambang 2015	Pursat extrapolated from Battambang	Average
Rainfall	Wet Season	+8%	+4%	+8%	+7.5%	+6.9%
	Dry Season	+1-2mm		-2.5%	-4%	-3.25%
Temperature	Wet Season	+3.2ºC	+1.7ºC	+2.6ºC	+3.5ºC	+2.5ºC
	Dry Season	+2.6ºC		+1.9ºC		+1.75ºC
Floods	Wet Season	No change	+9%			+9%
Drought	Dry Season	+15 days	+6 days			+10.5 days

168. From the above it can be seen that wet season rainfall may increase by 7%, dry season rainfall may drop -3%, wet season temperatures may increase by +2.5ºC and dry season temperatures by +1.75ºC. Flood occurrences and duration may increase by 9% and dry spells increase by 10 days. These projections are for the year 2050 under the A1B scenario which approximates to RCP6.0.

10.2. FRMI

169. The projections given in the FRMI software are based on current conditions and future values for 2055 under a high CO_2 climate change scenario which is RCP 8.5. They are a “broad brush” approach and one value can relate to upwards of 10kms of road. However they do cover the whole of Cambodia and despite limitations on their accuracy are considered useful.

10.3. NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP)

170. The NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset is comprised of downscaled climate scenarios for the whole world. They are derived from General Circulation Model (GCM) runs for two of the four greenhouse gas emissions scenarios Representative Concentration Pathways (RCPs) and were developed in support of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5).

171. The NEX-GDDP dataset includes RCP 4.5 and RCP 8.5 and gives daily maximum temperature, minimum temperature, and precipitation for the periods from 1950 through 2100.

172. The data covers the entire earth at a resolution of 0.25 degrees (~25 km x 25 km). An example of the screen is shown in Figure 10-1 below.

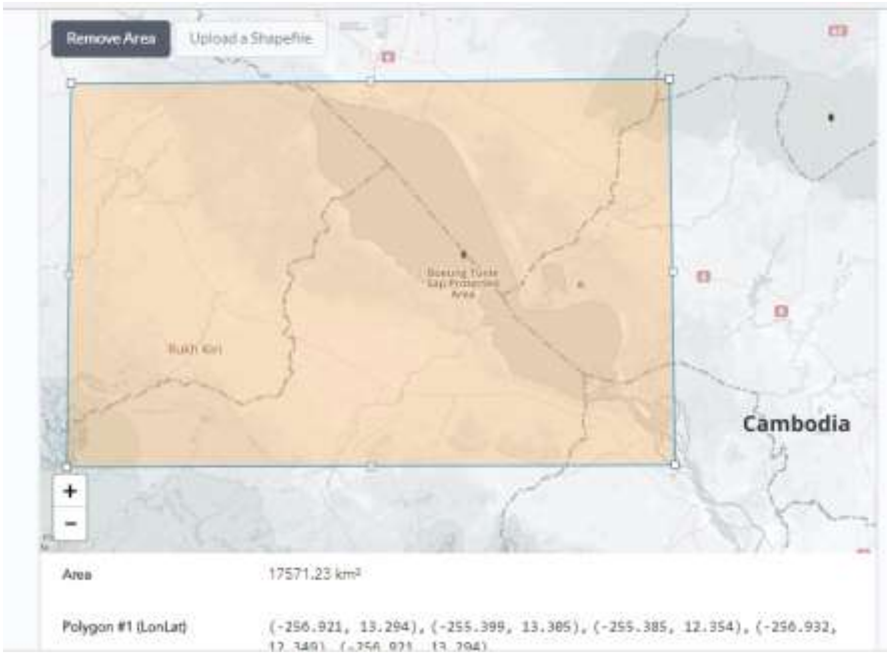


Figure 10-1 NASA NEX Screenshot

173. As it is beyond the resources of this project to carry out primary calculations, secondary data such as that available from NASA NEX will be used. This is discussed further in Section 19.

10.4. Choice of RCP

174. Some projections have been made for RCP6.0 and some for RCP8.5. The projections indicate that when extending out to 2050 and beyond there is not much difference between results for RCP 6.0 and RCP 8.5. For the purposes of this study RCP 4.5 and 8.5 will be adopted.

10.5. Time Steps

175. Much projected data is given as daily values but for design purposes often hourly or smaller time steps are recorded. IDF daily curves are available for all provinces.

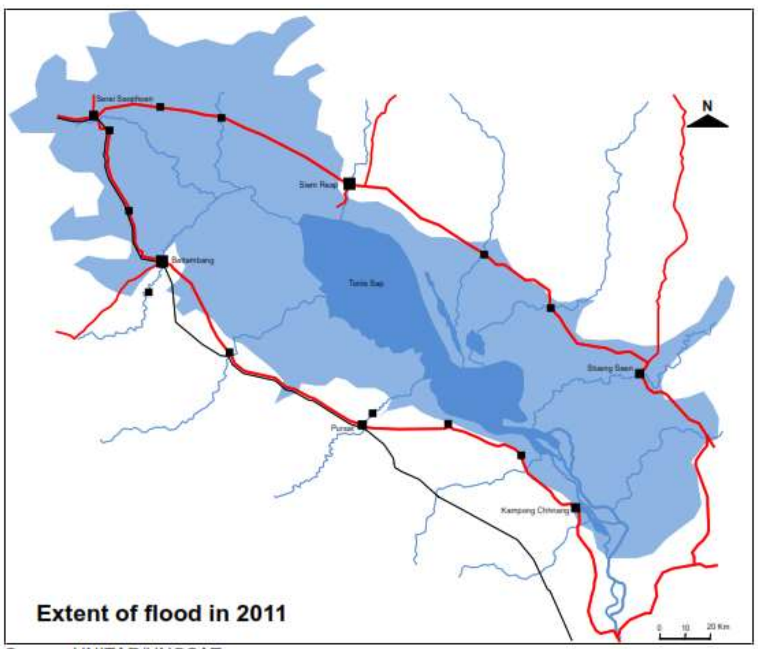
176. For the purposes of this study correction factors obtained by extrapolating downwards the data from Pochentong has been adopted.

11. FLOODING AND DROUGHT

11.1. Floods in Cambodia

177. Changes in the rainfall regime are the most important factors in climate change that can have an impact on physical infrastructure - much more important than, for example, temperature change. Flooding in Cambodia is a natural occurrence and lifestyles are adapted to seasonal floods. Most people are concerned when the intensity and occurrence changes. These events also create the greatest damage to infrastructure, as seen during typhoon Ketzana in October 2009, which was estimated to cause approximately $15 million in direct damages to the transport sector and a further $11 million in indirect losses through economic loss of access to communities.

178. There are two major flood types in Cambodia: (i) flashfloods, resulting from heavy downpour upstream on the Mekong River, which affect provinces along the Mekong and the southeastern areas of the country; and (ii) central area large scale floods, resulting from a combination of runoff from the Mekong River and heavy rains around the Tonle Sap Lake, which affect the provinces around the lake and the southern provinces. In low-lying areas with no natural gradient, flooding can last for weeks or months. Banteay Meanchey had the longest period of flooding at 68 days.



Source: UNITAR/UNOSAT

Figure 11-1 Extent of Historical Flooding in 2011 around Tonle Sap Lake

179. Rising temperatures due to climate change increase evaporation rates and also increase the capacity of the atmosphere to hold more water for longer periods of time. When the atmospheric water vapour is released as rain the precipitation is more severe and storms are more intense although possibly of shorter duration. If major rains occur after normal rainfall patterns, there has usually been sufficient rain to saturate soils. These are the preconditions for maximum run off and flooding. There are dams being built or planned in China and Laos, but only around 25% of the Mekong’s wet weather flow and less than 50% of its dry weather flow

originates from China[17]. These dams could have a substantial impact on the Mekong's hydraulic regime.

11.2. Lower Mekong Basin

180. Under USAID Mekong ARCC project, 2013 ICEM carried out downscaled projections for different areas of the Mekong basin, including Cambodia.[18] Figure 11-2 and 11-3 show the changes in average maximum daily temperatures in the dry season and wet season.

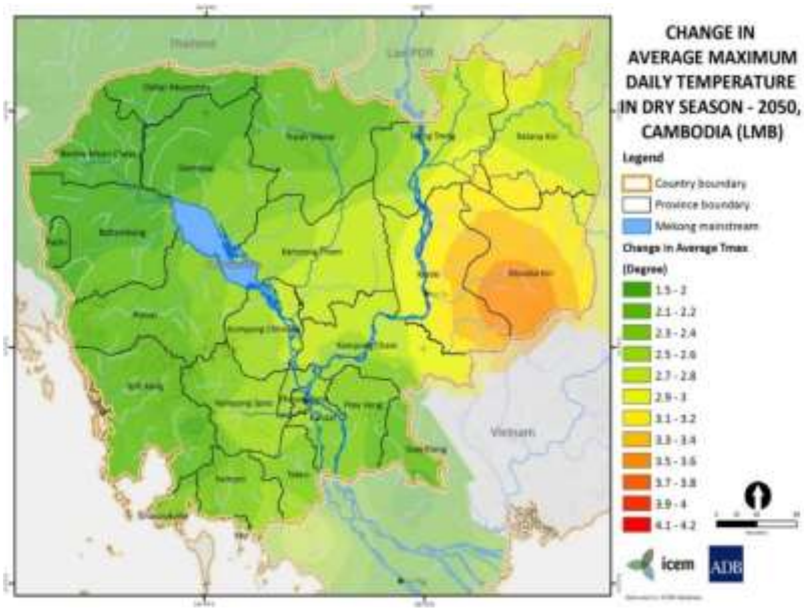


Figure 11-2 Change in average maximum daily temperature in the dry season – 2050

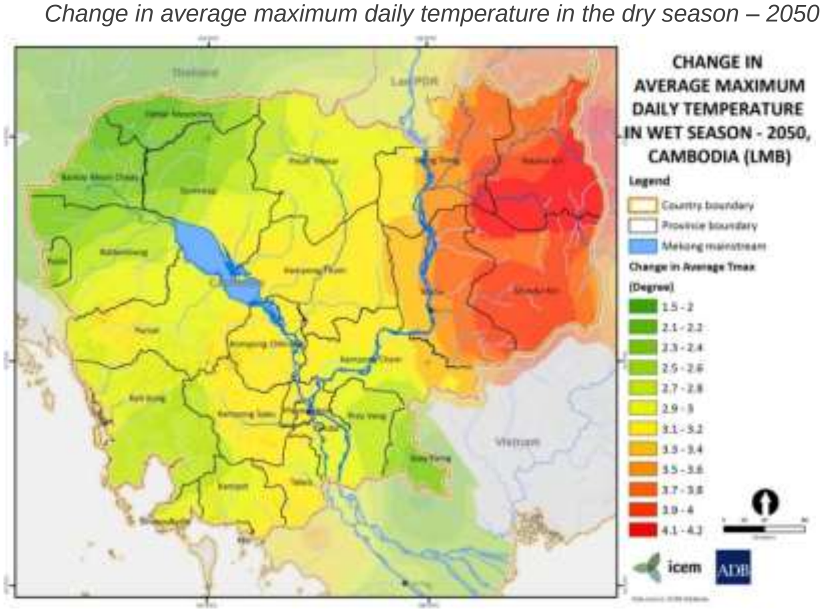


Figure 11-3 Change in average maximum daily temperature in the wet season by 2050

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[17] *Annual Flood Report and Yearbook, MRCS, Vientiane, 2008.*
[18] *USAID Mekong ARCC Climate change Impact and Adaptation Study for the Lower Mekong Basin. ICEM. 2013.*

181. Trends in rainfall are also expected to change over the coming decades. Seasonal variability in rainfall patterns is expected to grow resulting in wetter wet seasons (Figure 11-4, 11-5) and drier dry seasons. (Figure 11-6)

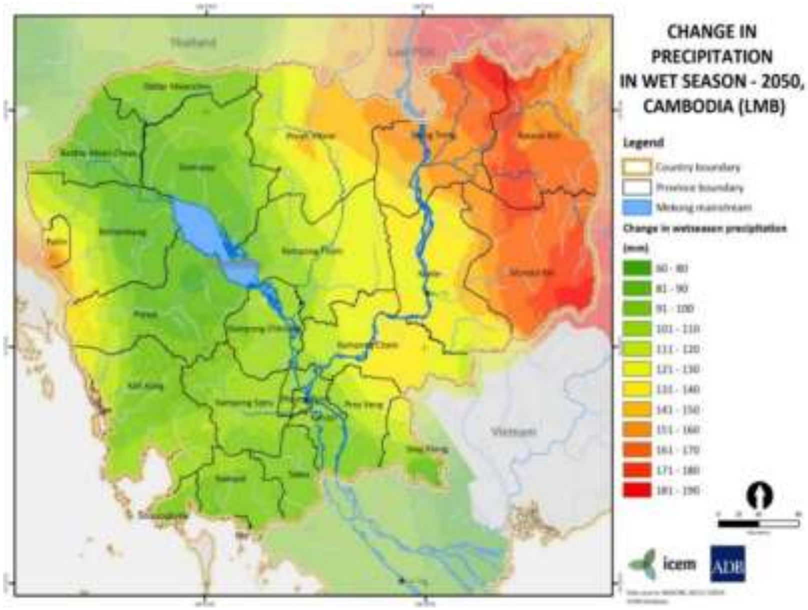


Figure 11-4 Increase in rainfall in the wet season – 2050

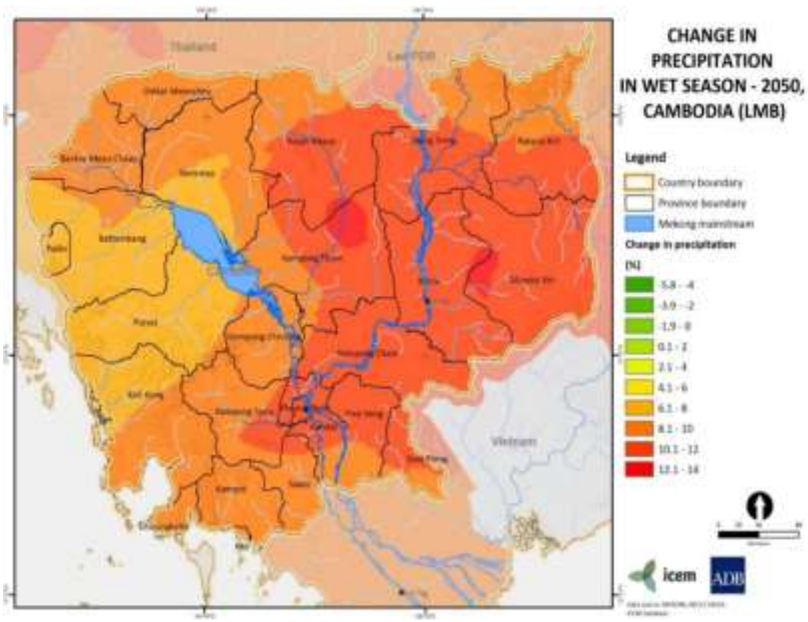


Figure 11-5 % change in rainfall in wet season – 2050

182. Changes in dry season rainfall are more variable depending on location. Large areas of Cambodia will receive a little less rainfall in the dry season – by up to 6mm. (Figure 11-6). However some may receive slightly more (2mm) in the dry season.

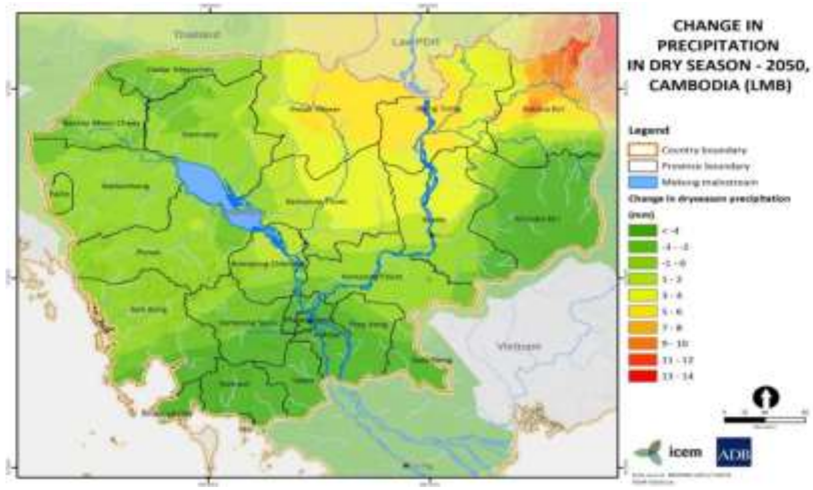


Figure 11-6 Change in rainfall during the dry season - 2050

183. While it is projected that average rainfall will increase in the basin, periods of annual agricultural drought are expected to lengthen significantly; particularly in the Mekong floodplain in Cambodia. Cambodia stands out as a hot spot with up to 30% increases in the number of drought days and months each year predicted in some provinces. (Figure 11-7).

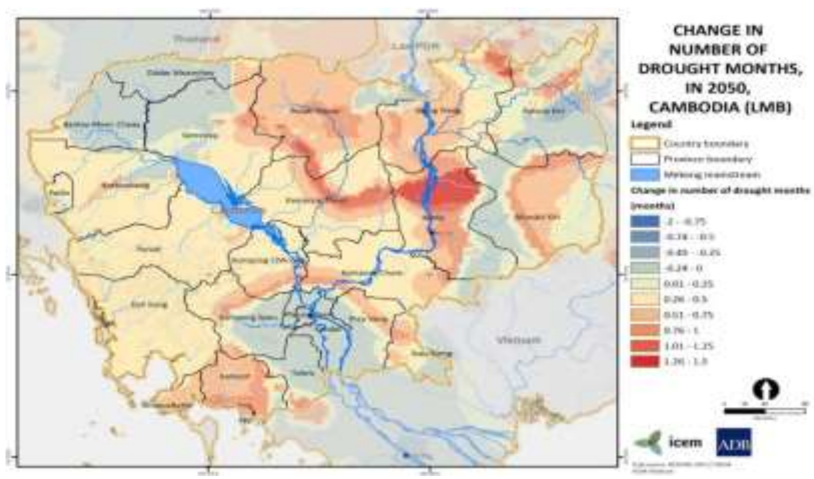


Figure 11-7 Change in number of drought months per year

11.3. Climate Change and Flood Levels

184. The rainfall increases and more intensive rainfall events will lead to increases in the extent, depth and duration of flooding throughout the country. For example the Mekong delta floodplains may experience significant increases of extreme floods with depths 2.0m (Figure 11-8).

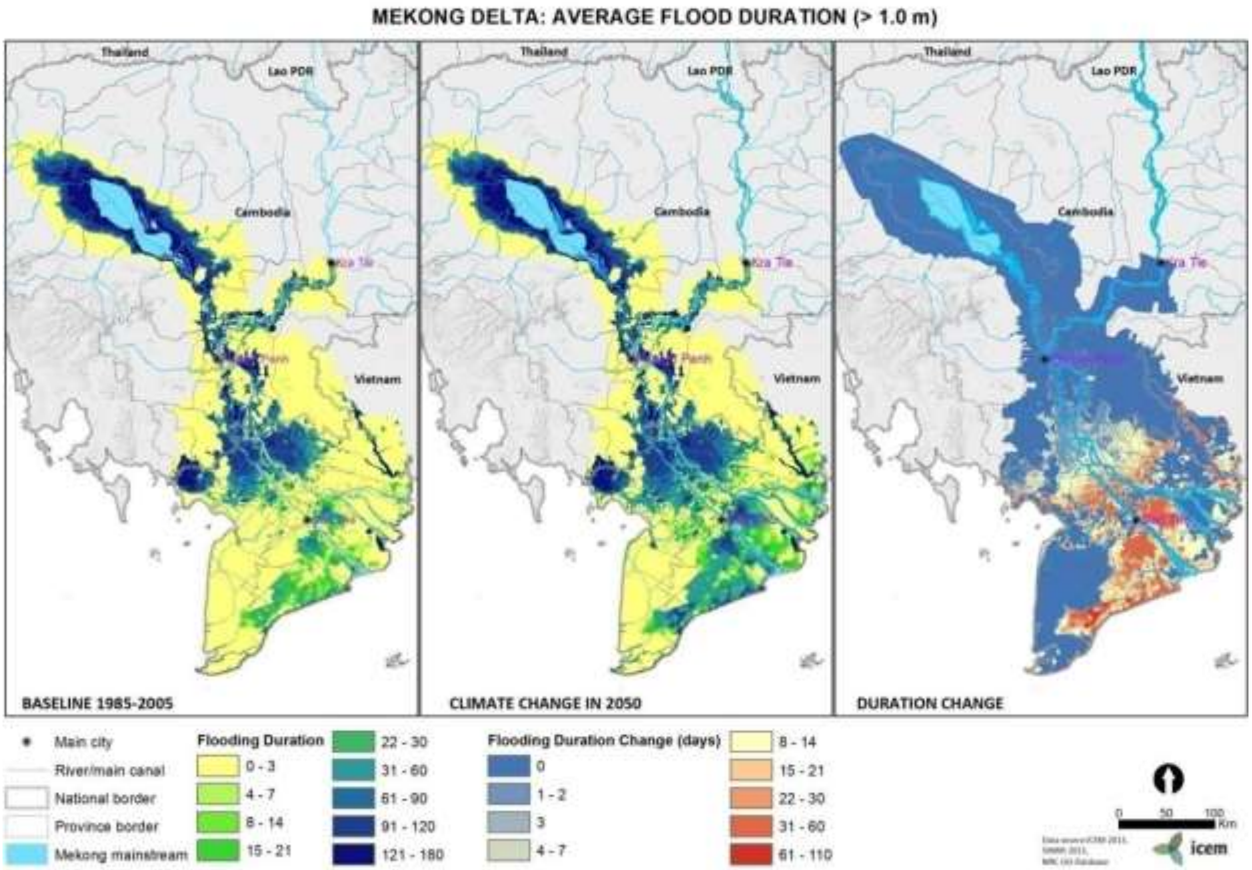


Figure 11-8 Projected flooding in the Mekong delta and floodplain – 2050

185. Climate change could also have an impact on the flood levels of the Tonle Sap. An overview of the expected consequences of climate change between 2020 and 2050 has been carried out by the Mekong River Commission (MRC)[19]. The main predictions relating to flood levels and river flows in Cambodia are the following:

- The mean annual rainfall in Cambodia will be unchanged or even decrease by up to 8%. The largest increase is expected in the wet season, but will also occur in the dry season in Upper Mekong
- The Mekong's flow is expected to increase by 4 to 13 % in the wet season and by 10 to 30 % in the dry season. The largest increases will appear from the Chinese border to Kratie in Cambodia.
- The snow melt contribution from the Upper Mekong is expected to increase and to start earlier due to increased temperatures.
- The increased flow in the Mekong will improve water availability in the dry season, but also increase the risk of flooding in the wet season. The low-lying areas downstream of Kratie

[19] *Impacts of climate change and development on Mekong flow regimes. First assessment – 2009, Mekong River Commission Technical Paper No. 29, June 2010.*

including the Tonle Sap area are expected to be particularly at risk. The areas affected by flooding due to rainfall and upstream flow from Mekong are estimated to increase by 9% not including effects of a possible sea level rise. Areas with flooding depths higher than two meters are estimated to increase by almost 40%.

- The storage capacity of hydropower installations may potentially reduce impacts of flooding in some areas. The Lower Mekong Basin 20-year development plan alone estimates a decrease of the wet season river flow by 7 to 17%, while the climate change scenarios for this season estimate a flow increase of between 2 to 11%. The combined counterbalancing effect is expected to vary between a decrease of 13% to an increase of 3%.

186. Importantly, the report states that there is a high degree of uncertainty related to both the climate change scenarios and the different development plans in the basin.

187. Another 2010 study[20] indicates that by 2050 the average water levels in the Tonle Sap may increase by 0.2m and peak water levels may increase by up to 0.3m. This study estimated flood durations to be 9% cent longer under anticipated climate change conditions and therefore the probability of coincidence with river floods is likely to increase. However, the 2010 study also considers the development of water infrastructure along the Mekong River and its impact on reducing downstream flood impact under climate change conditions. It concludes that while the two phenomena may balance each other, further detailed studies are required.

11.4. Drought and Climate Change

188. It is likely that annual rain fall will remain constant, or even decrease, but short term rainfall will increase. This will lead to longer periods in between rainfall. These longer periods between rainfall cause an increase in drought.

Drought has devastating effects on agriculture. There are four characteristics of agricultural drought in Cambodia:

(i) unpredictable delays in rainfall onset in the early wet season,
(ii) erratic variations in wet season rainfall onset, amount, and duration across different local areas,
(iii) early ending of rains during the wet season, and
(iv) common occurrence of mini-droughts of three weeks or more during the wet season which can damage or destroy rice crops without irrigation. Many farmers report that they fear drought more than flood.

In 2015 most of the 25 provinces of Cambodia experienced water shortages due to what was considered a one in 50 years drought. According to the National Committee for Disaster Management (NCDM), Banteay Meanchey, Battambang, Pursat, and Kampong Speu provinces were the worst affected, with around 2.5 million people in 625,000 households severely affected. Although rains improved from late July 2016 over most of the country, bringing relief to the drought-affected areas, farming households with little resilience and low agricultural productivity struggled to recover fully.

[20] *"Modeling climate change impacts on the flood pulse in the Lower Mekong floodplains." Annual Flood Report and Yearbook, MRCS, Vientiane, 2008.*

There may be an increase in Annual Drought Months due to climate change. By 2050, average annual number of drought months would increase in Kampong Thom by about 0.6 months; in Siem Reap it may increase by about 0.2 months; in Battambang it may increase in the southern part of the province and also in Kampong Chhnang increase in the south of the province. (Figure 11-9)

Figure 11-9 Impacts of 2015 Drought

12. KAMPONG CHHNANG PROVINCE

12.1. Location

189. In Kampong Chhnang, residents are affected by flooding from the Tonle Sap lake which causes the most inundation damage, and the run-off from the hills around the town. The annual hydrological cycle of the Tonle Sap is the main cause of flooding. The existing embankment along the Tonle Sap was overtopped in 2011 and resulted in severe flooding. It is the government's first priority for climate resilient infrastructure investment.

Figure 12-1 Location Kampong Chhnang

Figure 12-2 Kampong Chhnang 2011 Floods

12.2. Rainfall Kampong Chhnang

190. Rainfall data in Kampong Chhnang shows that rainfall over the last 15 years has been variable, but does seem to be increasing since 2006. In 2011 the highest rainfall occurred and this coincided with the flooding in the town when the existing embankment was overtopped. However, more intensive precipitation could cause the Mekong River levels to rise.

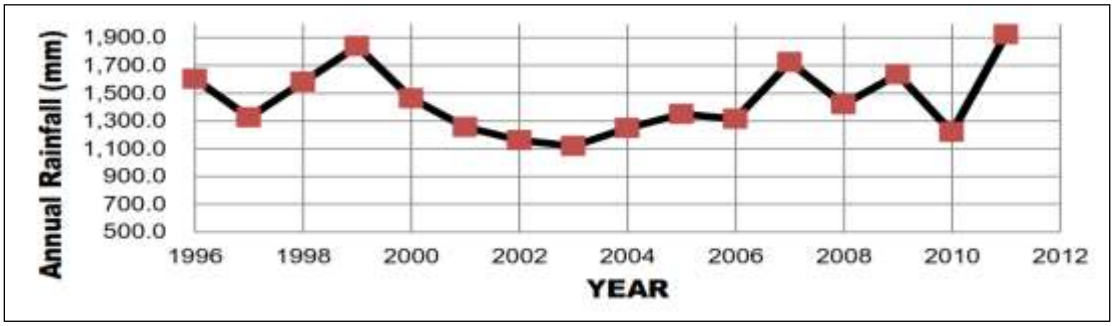


Figure 12-3 Annual Rainfall in Kampong Chhnang

Rainfall data for Kampong Chhnang is given below.

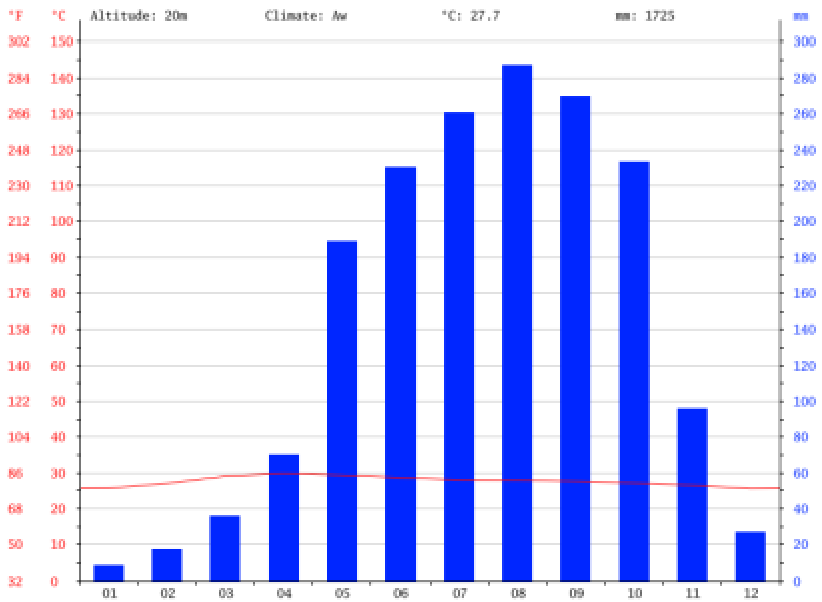


Figure 12-4 Monthly Rainfall in Kampong Chhnang

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	25.7	27	29	29.8	29.3	28.6	28	27.9	27.6	27.1	26.5	25.6
Min. Temperature (°C)	20.3	21.7	24	24.9	24.9	24.6	24.4	24.4	24.2	23.7	22.5	20.8
Max. Temperature (°C)	31.1	32.3	34	34.7	33.7	32.7	31.7	31.5	31	30.5	30.5	30.4
Avg. Temperature (°F)	78.3	80.6	84.2	85.6	84.7	83.5	82.4	82.2	81.7	80.8	79.7	78.1
Min. Temperature (°F)	68.5	71.1	75.2	76.8	76.8	76.3	75.9	75.9	75.6	74.7	72.5	69.4

	January	February	March	April	May	June	July	August	September	October	November	December
Max. Temperature (°F)	88.0	90.1	93.2	94.5	92.7	90.9	89.1	88.7	87.8	86.9	86.9	86.7
Precipitation / Rainfall (mm)	9	17	36	70	189	230	261	287	270	233	96	27

Figure 12-5 Monthly Climate Kampong Chhnang

The precipitation varies 278 mm between the driest month and the wettest month. The variation in annual temperature is around 4.2 °C.

12.3. Climate Change Threat Profile Kampong Chhnang

The Kampong Chhnang Province Climate Change threat profile is given below :

Table 12-1 Projected changes to average rainfall & maximum temperatures by 2050:

Climate change parameter	Baseline	With C.C.	Change
Average annual rainfall:	1376 mm	1479 mm	+7.5%
Total rainfall in wet season:	1144 mm	1248 mm	+9.1 %
Total rainfall in dry season (Nov - Apr):	232 mm	231 mm	-0.3 %
Average daily maximum temperature (Annual)	29.2 °C	32.0 °C	+2.8 °C
Average maximum temperature in wet season:	28.3 °C	31.3 °C	+3.0 °C
Average maximum temperature in dry season:	30.1 °C	32.6 °C	+2.5 °C

12.4. Projected changes to average rainfall & maximum temperatures by 2050

12.4.1. Wet season rainfall

By 2050, total rainfall in the wet season in Kampong Chhnang would increase by about 9.11%.

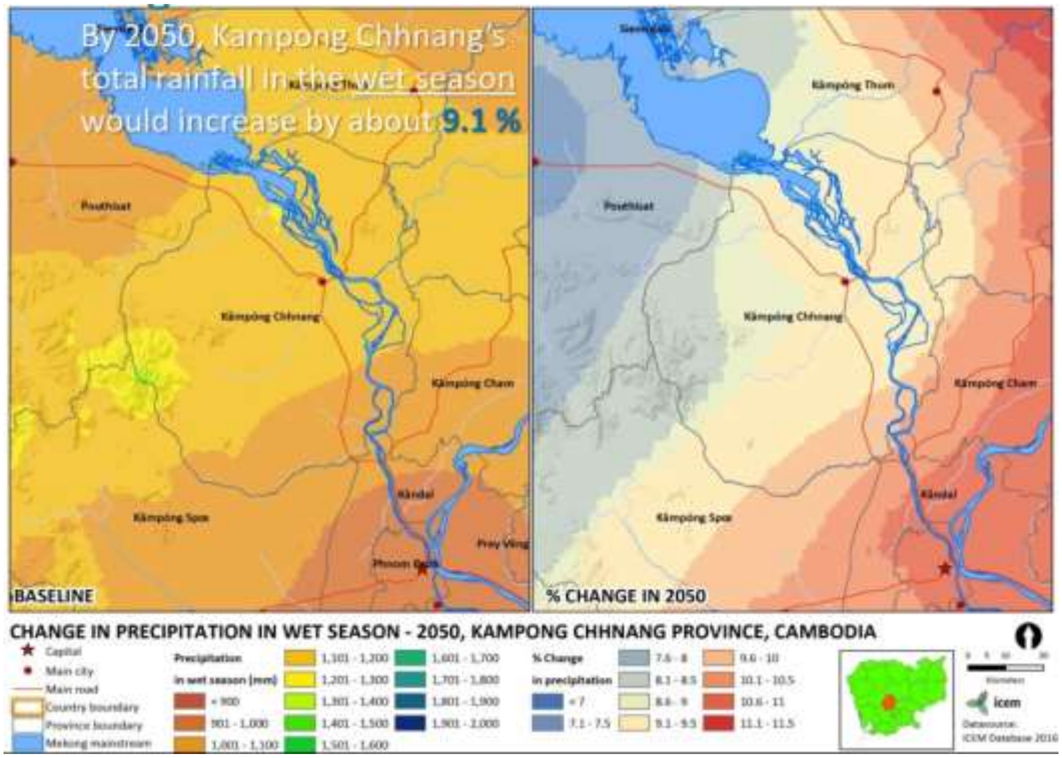


Figure 12-6 Changes in Rain fall in Wet Season

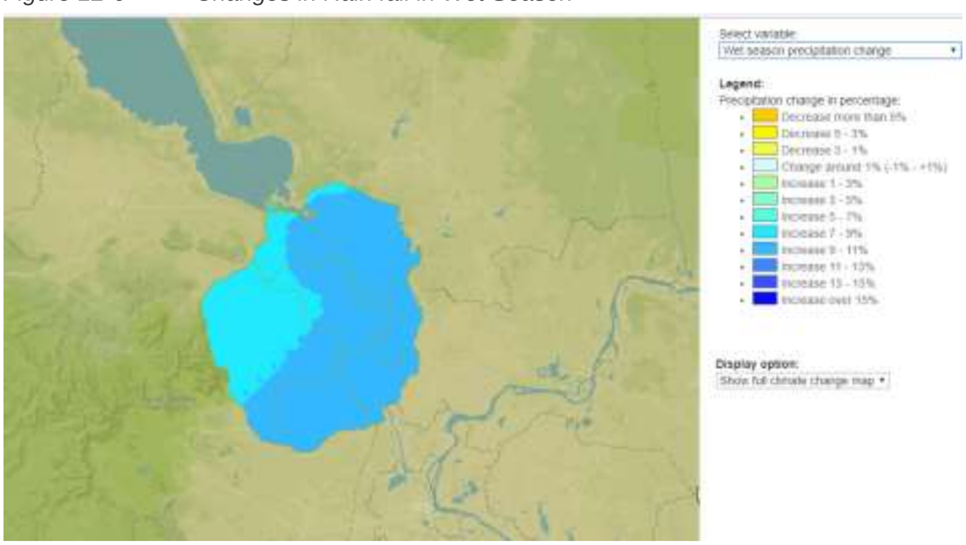


Figure 12-7 Wet Season Precipitation Change

12.4.2. Dry season rainfall

By 2050, total rainfall in Kampong Chhnang in the dry season would decrease about -0.3%.

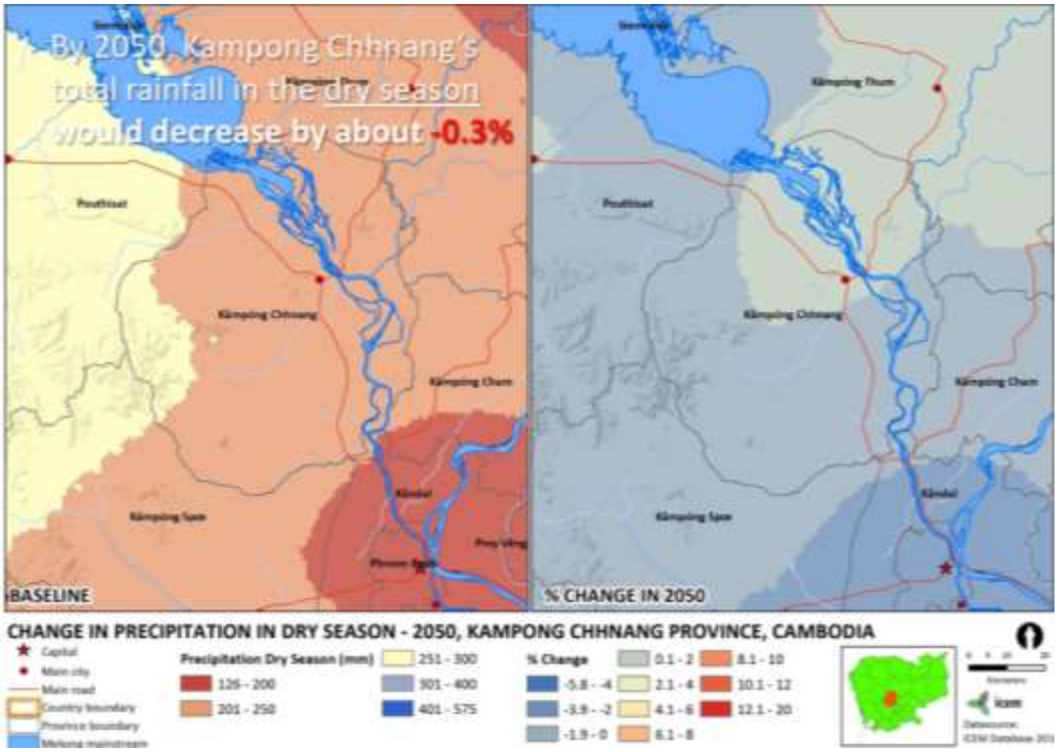


Figure 12-8 Changes in Rain fall in Dry Season

Figure 12-9 Dry Season Precipitation Change

12.4.3. Wet season temperature

By 2050, the average daily maximum temperature in the wet season in Kampong Chhnang would increase by about 3.0^{0}C.

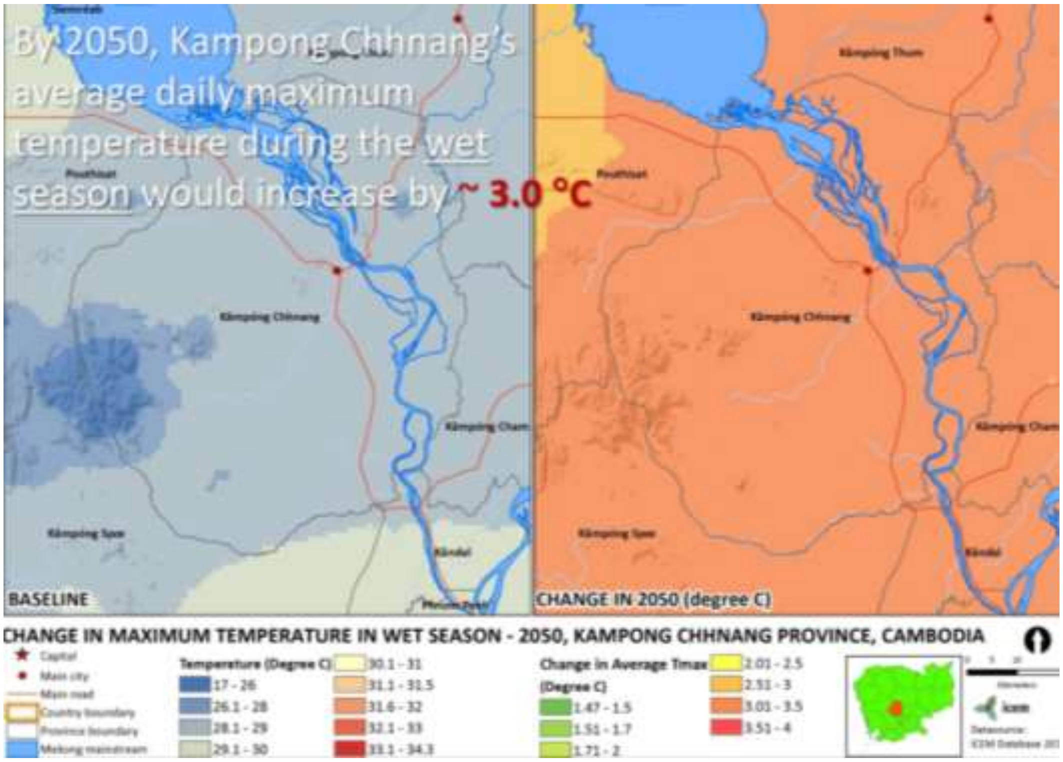


Figure 12-10 Changes in Temperatures in Wet Season

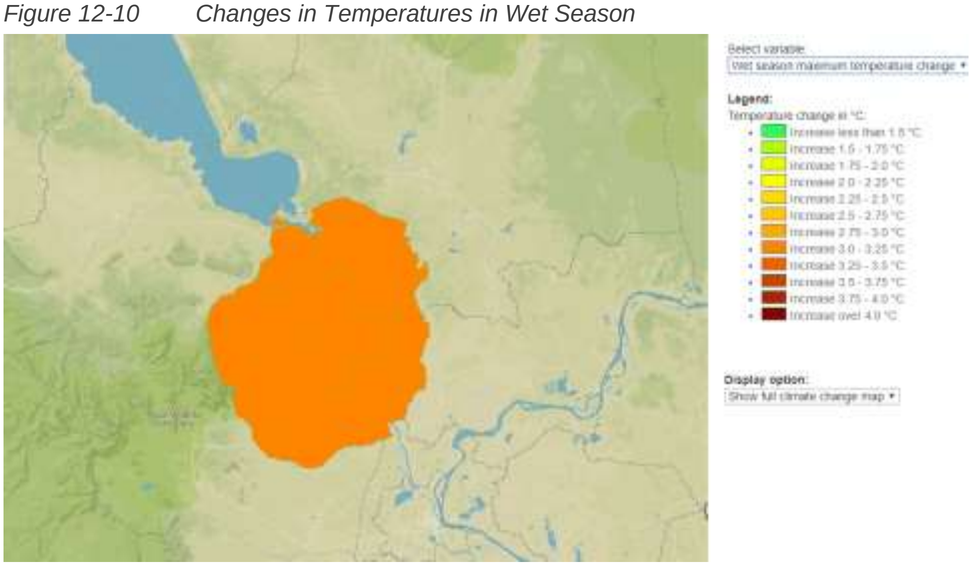


Figure 12-11 Wet Season Maximum Temperature Change

12.4.4. Dry season temperature

By 2050, the average daily max temperature in Kampong Chhnang in the dry season would increase by about 2.5^{0}C.

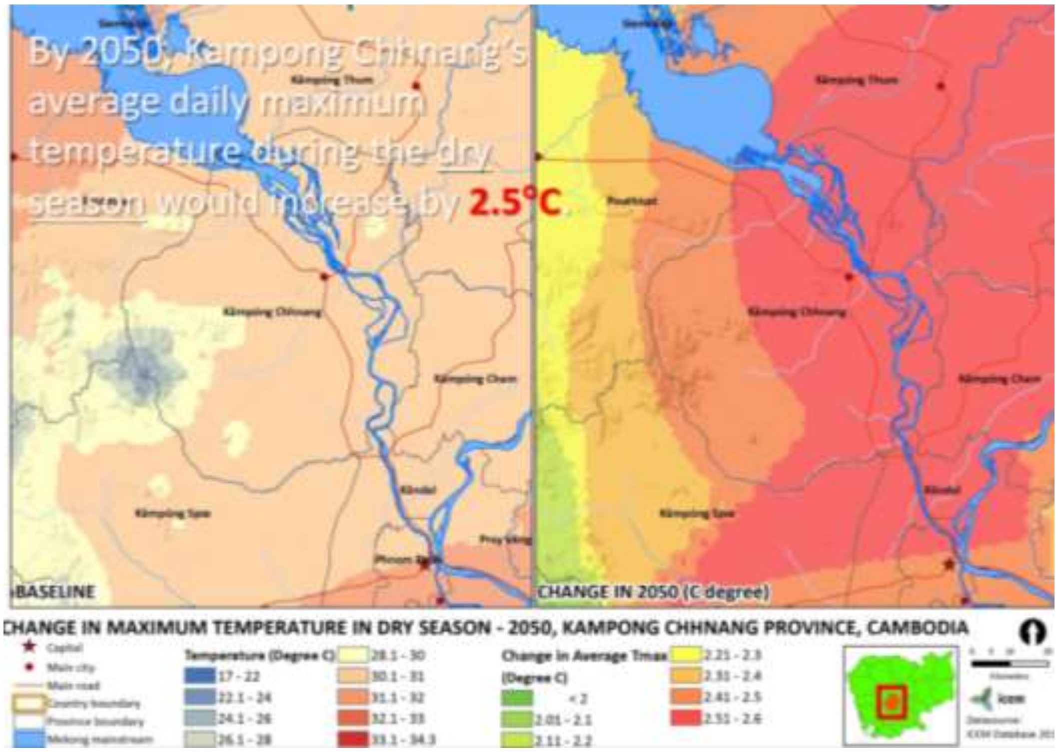


Figure 12-12 Changes in Temperatures Dry Season

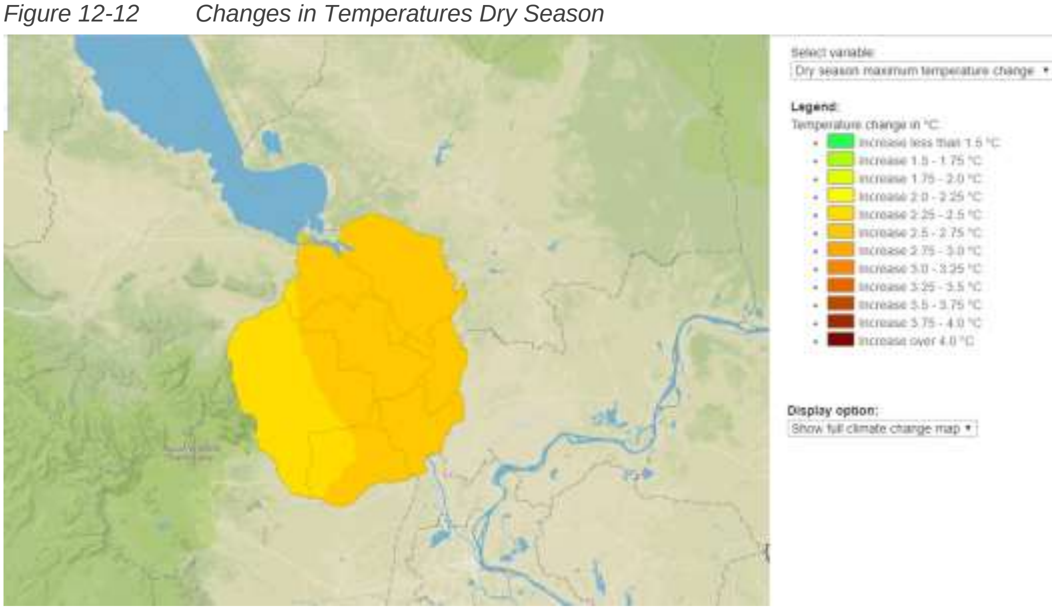


Figure 12-13 Dry Season Maximum Temperature Change

Table 12-2 Climate Change by District

Detailed climate change data by district:

No.	District	Maximum temperature (°C)						Precipitation (mm)					
		Dry season			Wet season			Dry season			Wet season		
		Baseline	2050	Changes	Baseline	2050	Changes	Baseline	2050	Changes	Baseline	2050	Changes
1	Baribour	30.4	32.9	2.5	28.5	31.5	3	235	235	0.2%	1174	1279	8.9%
2	Chol Kiri	30.3	32.9	2.6	28.3	31.4	3	223	222	-0.4%	1123	1228	9.3%
3	Kampong Chhnang	30.2	32.8	2.6	28.3	31.3	3	230	230	0.3%	1175	1282	9.1%
4	Kampong Leaeng	30.3	32.9	2.6	28.3	31.3	3	230	231	0.4%	1177	1285	9.1%
5	Kampong Tralach	30.4	33	2.6	28.6	31.6	3	215	213	-1%	1077	1180	9.6%
6	Rolea B'ier	30.3	32.8	2.6	28.4	31.4	3	231	231	0.1%	1165	1270	9.1%
7	Sameakki Mean Chey	30.3	32.8	2.5	28.6	31.7	3	219	216	-1.2%	1080	1182	9.5%
8	Tuek Phos	29.6	32.1	2.5	27.8	30.8	3	245	244	-0.4%	1156	1257	8.7%

Total: 8 districts

12.4.1. Kampong Chhnang Floods

Kampong Chhnang is likely to be hotter and wetter in the wet season which will lead to increased severity of flooding (where flooding already occurs), potentially new areas of flooding, increased flows of the Mekong River and floods would be deeper and of longer duration.

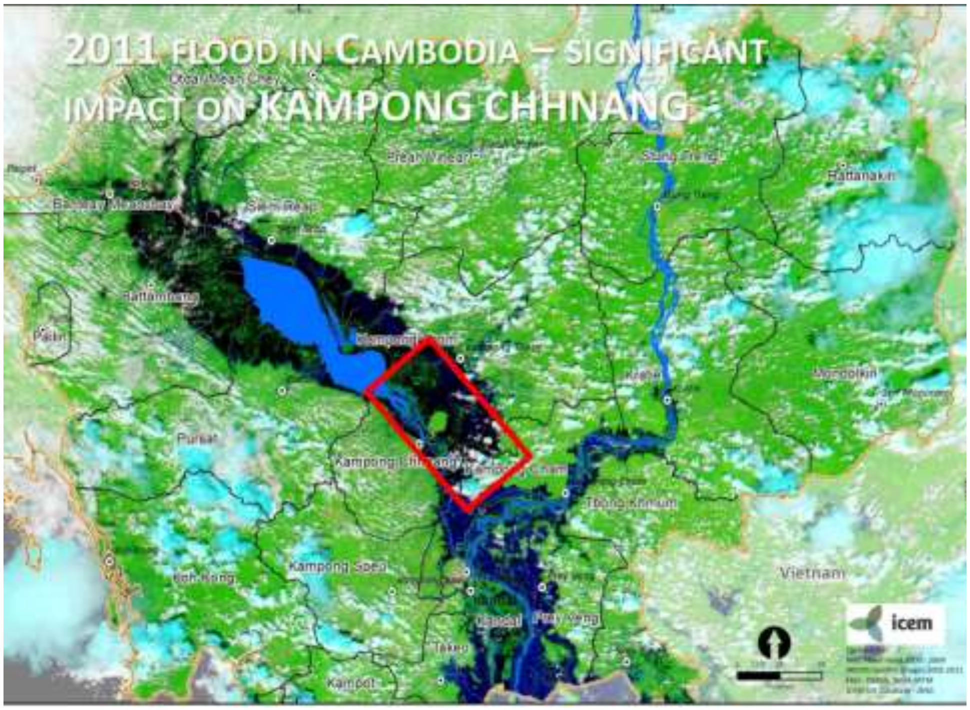


Figure 12-14 Kampong Chhnang 2011 Floods

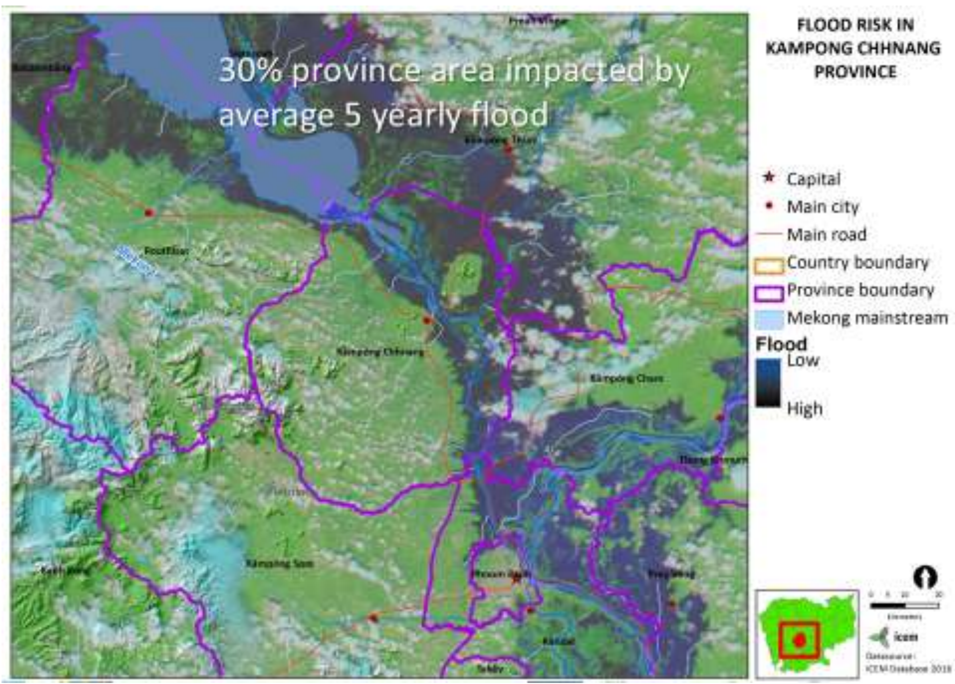


Figure 12-15 Kampong Chhnang Flood Risk

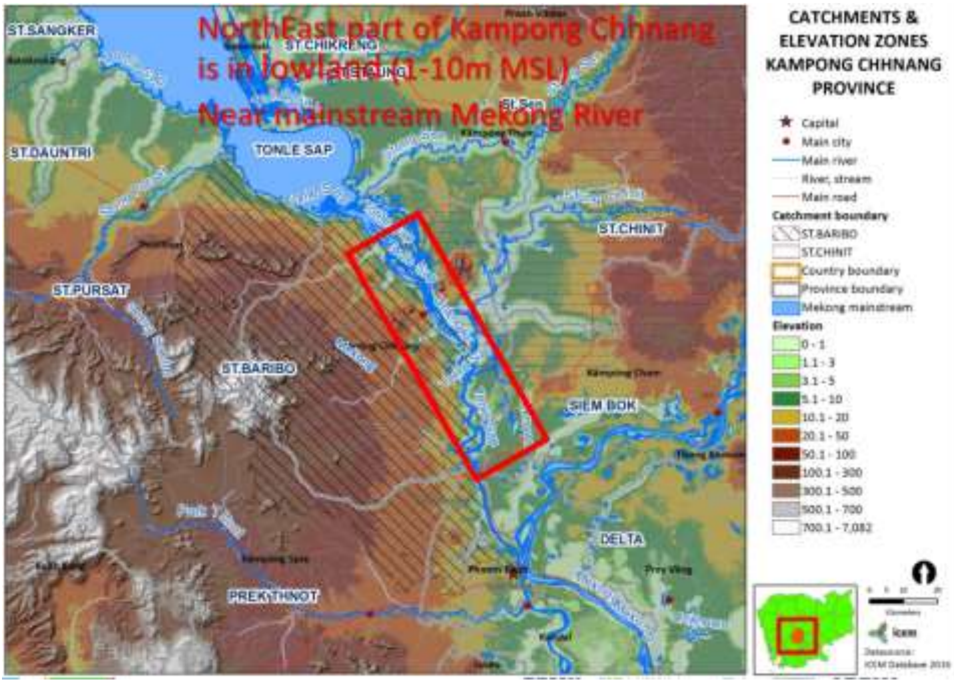


Figure 12-16 Kampong Chhnang Catchments

12.4.1. Kampong Chhnang Drought

Kampong Chhnang is likely to be significantly hotter and wetter in the wet season and significantly hotter and slightly dryer in the dry season.

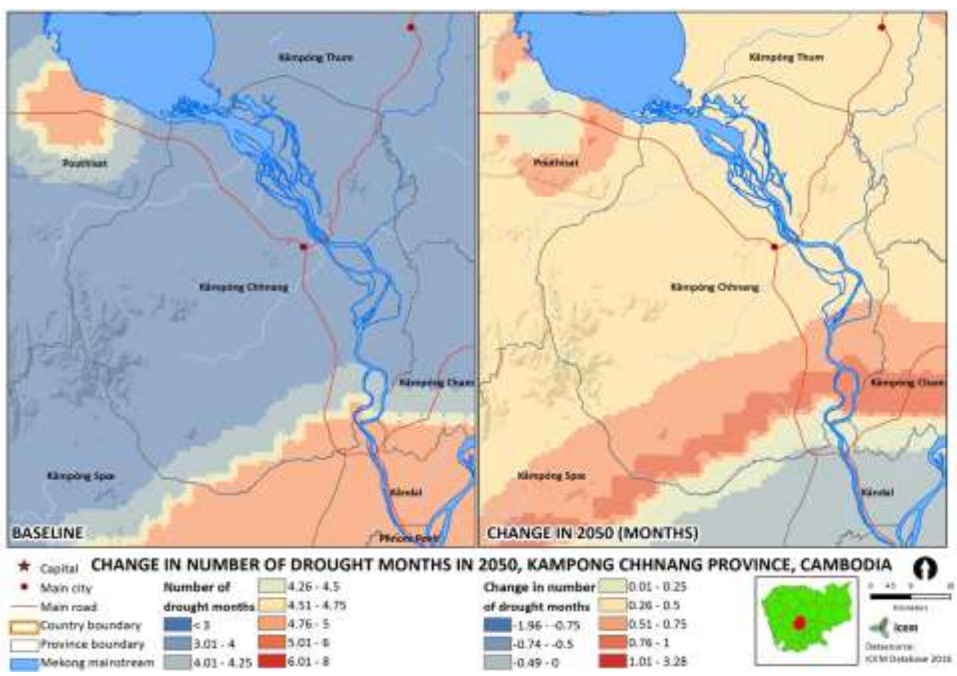


Figure 12-17 Kampong Chhnang Droughts Months

12.5. FRMI Climate Change Risks

191. The flood risk map for Kampong Chhnang Province is shown below.

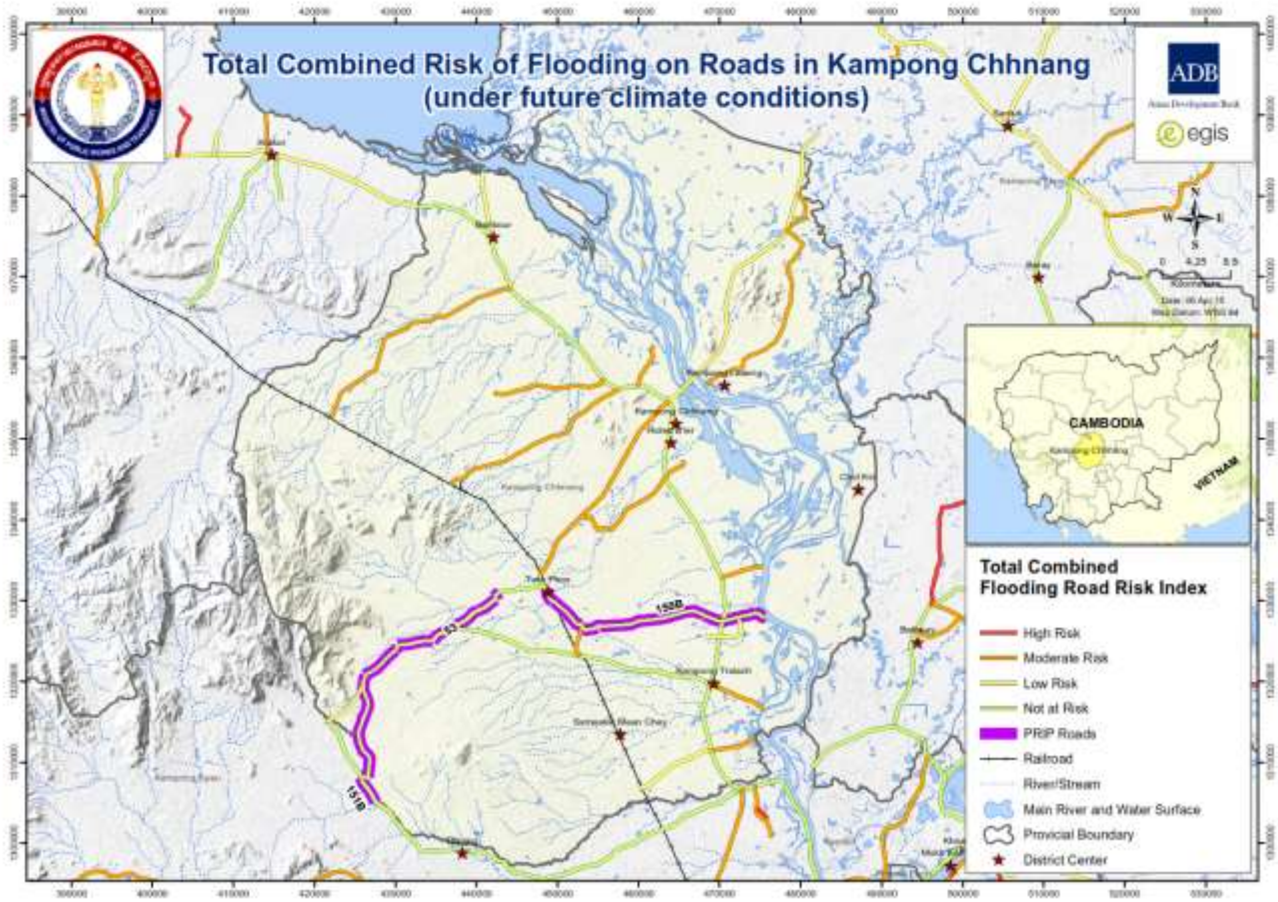


Figure 12-18 FRMI Flood Risk Map Kampong Chhnang Province

192. Roads on embankments are classified as being at **Low risk** of flooding but surrounding low lying areas are at **Moderate Risk**.

12.6. Rainfall Intensity-Duration-Frequency (IDF) Curves for Kampong Chhnang Province

Table 12-3 Kampong Chhnang IDF

Duration t		Intensity-Duration-Frequency (mm/hrs) Kampong Chhnang								
		Return Period, T								
		2	**3**	**4**	**5**	**10**	**20**	**25**	**50**	**100**
5	min	157	183	200	212	249	284	295	299	330
10	min	128	149	163	173	203	232	241	248	273
15	min	109	127	138	147	172	197	204	212	234
30	min	75.7	88	96	102	120	137	142	150	166
1	h	48.3	56.4	61.6	65.4	77	88	91	97	107
2	h	29.0	33.8	36.9	39.2	46.0	52.5	54.5	59.0	65.2
4	h	16.7	19.5	21.3	22.6	26.5	30.3	31.4	34.4	38.0
8	h	9.4	11.0	12.0	12.8	15.0	17.1	17.7	19.6	21.6
12	h	6.7	7.8	8.5	9.1	10.6	12.1	12.6	14.0	15.4
18	h	4.8	5.5	6.1	6.4	7.5	8.6	9.0	10.0	11.0
24	h	3.7	4.3	4.7	5.0	5.9	6.7	7.0	7.8	8.6

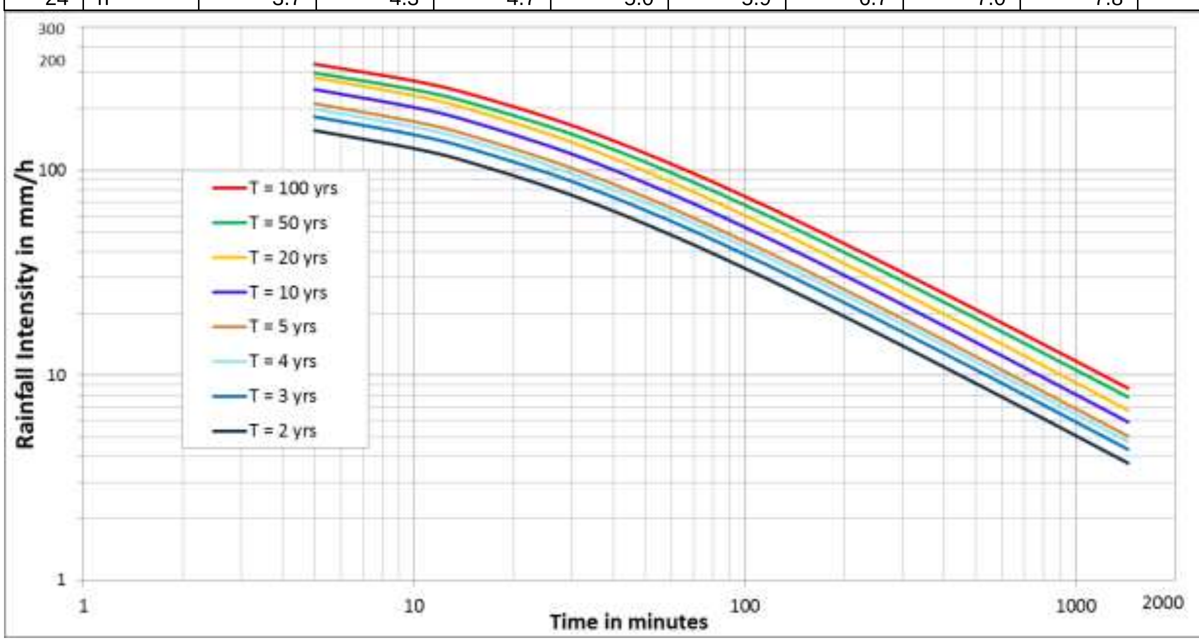


Figure 12-19 Kampong Chhnang IDF

13. PURSAT PROVINCE

13.1. Location

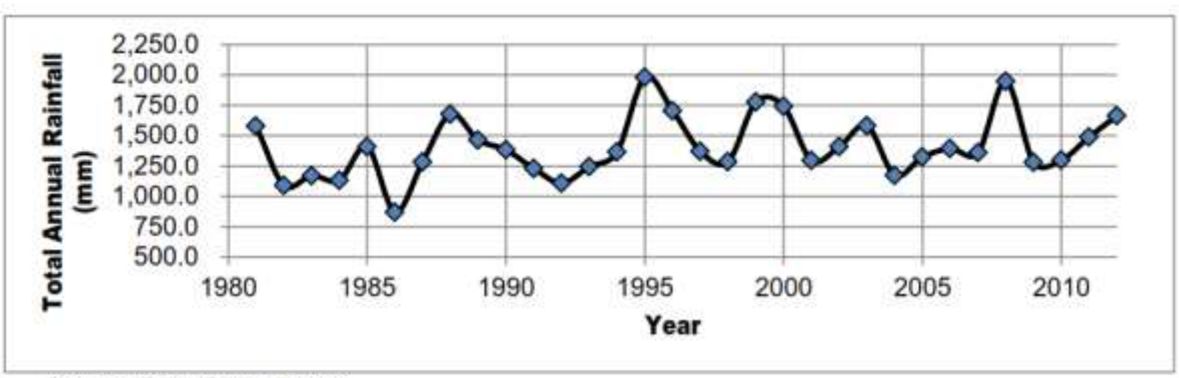
193. In Pursat, residents are affected by flooding from both the Pursat River and lack of drainage, which causes the most inundation damage in the town center and affects 80% of the area.

194. The town center lies in a depression and the natural slope of the town is away from the river towards old channels of the Pursat River. While the embankment along the Pursat River was also overtopped by the 2011 floods, it occurs less frequently and can be managed through sandbags along the river edge.

Figure 13-1 Location Pursat

13.2. Rainfall Pursat

195. Detailed rainfall data for Pursat is available from 1981 and Figure 7-1 shows the variation in total annual rainfall over this period. However, this data is insufficient to prepare the intensity-duration-frequency (IDF) curves that would allow an accurate estimation of the time of concentration and thus the intensity of rain fall over a short duration such as one hour.



Source: PDWRAM, Pursat

Figure 13-2 Total Annual Rainfall in Pursat

Rainfall data for Pursat is given below.

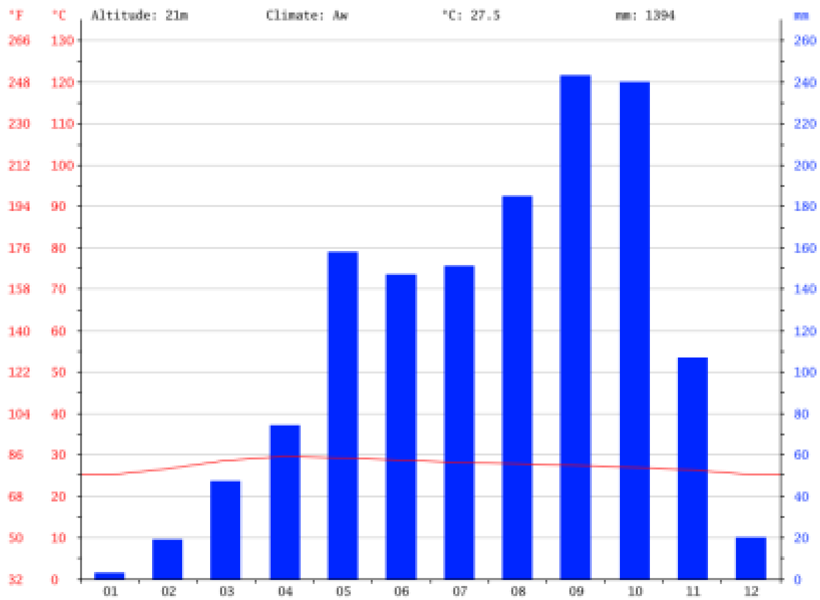


Figure 13-3 Climatograph Pursat

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	25.1	26.6	28.6	29.6	29.2	28.7	28.1	27.8	27.4	26.9	26.3	25.2
Min. Temperature (°C)	19.6	21.3	23.5	24.7	24.9	24.8	24.5	24.3	24	23.4	22	20
Max. Temperature (°C)	30.6	32	33.7	34.5	33.6	32.6	31.8	31.3	30.9	30.4	30.6	30.4
Avg. Temperature (°F)	77.2	79.9	83.5	85.3	84.6	83.7	82.6	82.0	81.3	80.4	79.3	77.4
Min. Temperature (°F)	67.3	70.3	74.3	76.5	76.8	76.6	76.1	75.7	75.2	74.1	71.6	68.0
Max. Temperature (°F)	87.1	89.6	92.7	94.1	92.5	90.7	89.2	88.3	87.6	86.7	87.1	86.7
Precipitation / Rainfall (mm)	3	19	47	74	158	147	151	185	243	240	107	20

Figure 13-4 Monthly Climate Pursat

The precipitation varies 240 mm between the driest month and the wettest month. Throughout the year, temperatures vary by 4.5 °C

13.3. Climate Change Threat profile Pursat Province

The Pursat Province Climate Change threat profile is given below:

Table 13-1 Projected changes to average rainfall & maximum temperatures by 2050:

Climate change parameter	Baseline	With C.C.	Change
Average annual rainfall:	1546 mm	1641 mm	**+6.1 %**
Total rainfall in wet season:	1267 mm	1363 mm	**+7.6 %**
Total rainfall in dry season (Nov - Apr):	279 mm	278 mm	**-0.4 %**
Average daily maximum temperature (Annual)	29.0 °C	31.6 °C	**+2.6 °C**
Average maximum temperature in wet season:	28.0 °C	31.0 °C	**+3.0 °C**
Average maximum temperature in dry season:	29.9 °C	32.1 °C	**+2.2 °C**

13.4. Projected changes to average rainfall & maximum temperatures by 2050

13.4.1. Wet season rainfall

By 2050, total rainfall in the wet season in Pursat may increase about 6.7%.

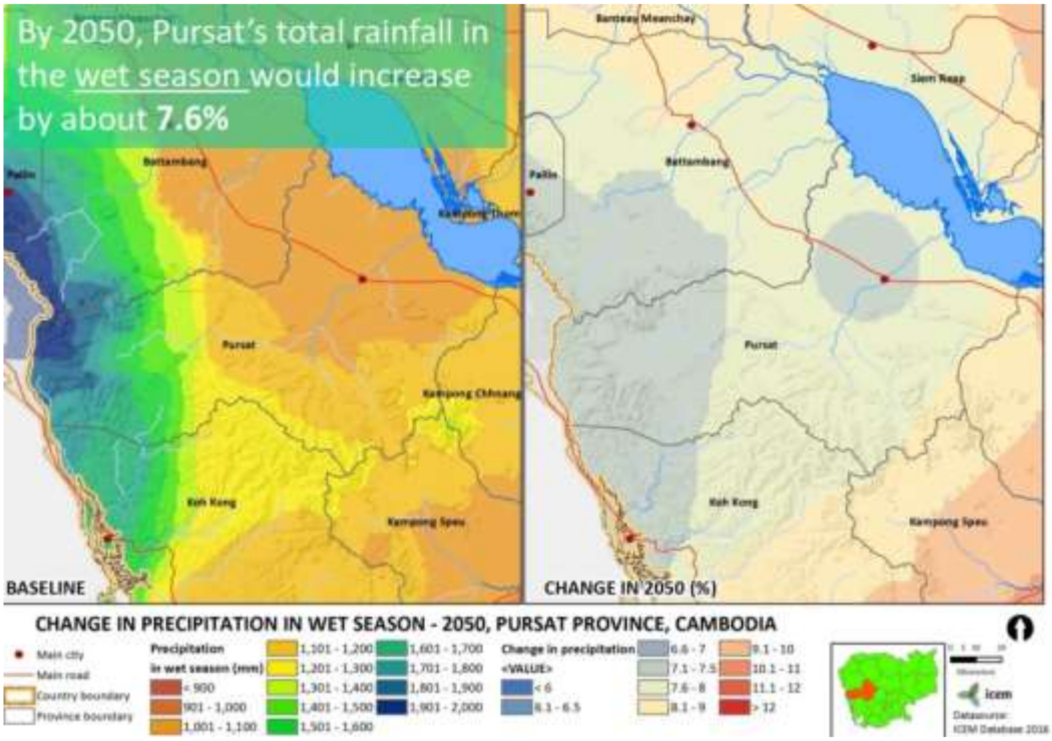


Figure 13-5 Changes in Rain fall in Wet Season

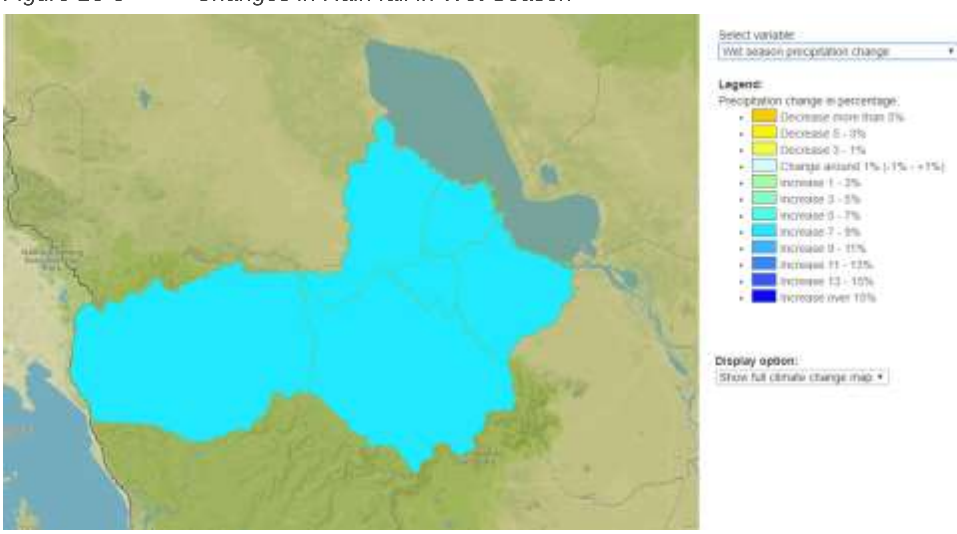


Figure 13-6 Wet Season Precipitation Change

13.4.2. Dry season rainfall

By 2050, total rainfall in the dry season in Pursat may decrease by about -0.4%.

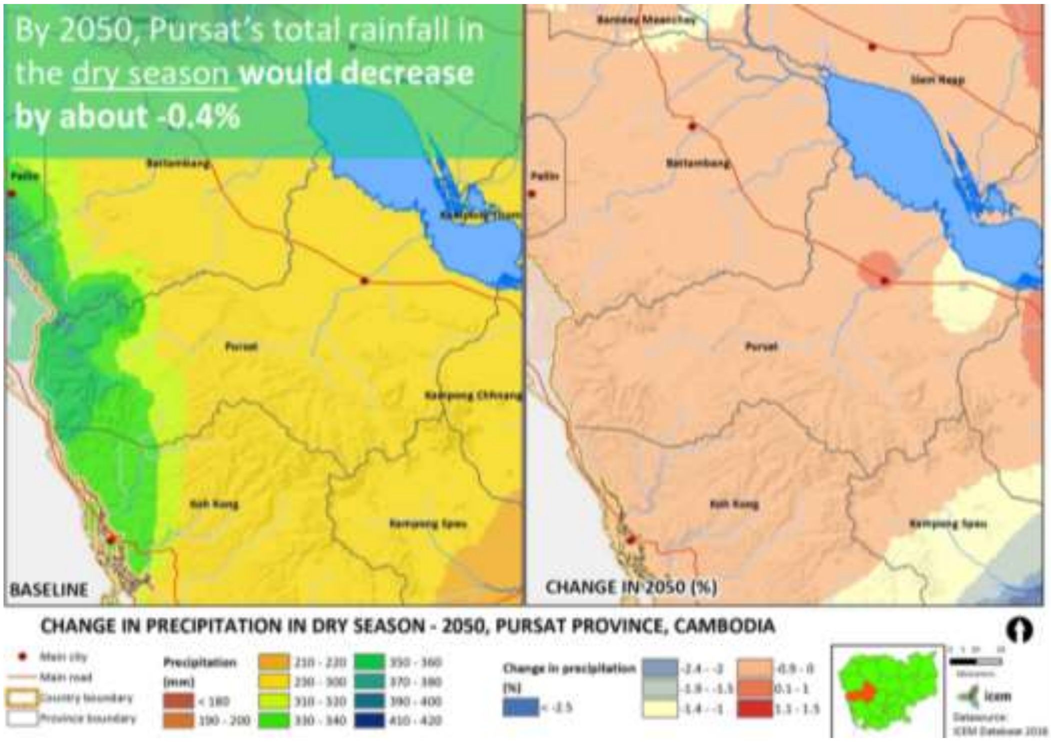


Figure 13-7 Changes in Rain fall in Dry Season

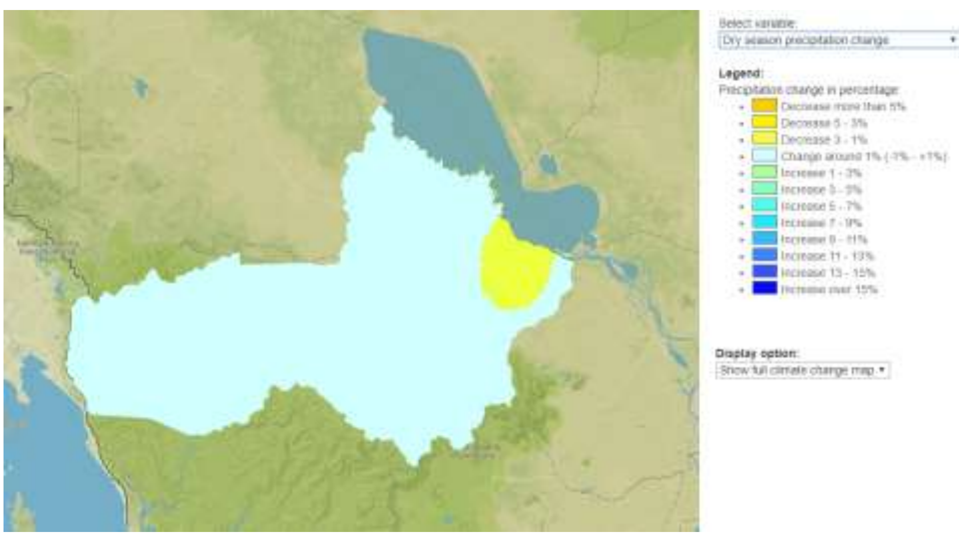


Figure 13-8 Dry Season Precipitation Change

13.4.3. Wet season temperature

By 2050, the average daily maximum temperature in Pursat in the wet season would increase by about 3.0 ^{0}C

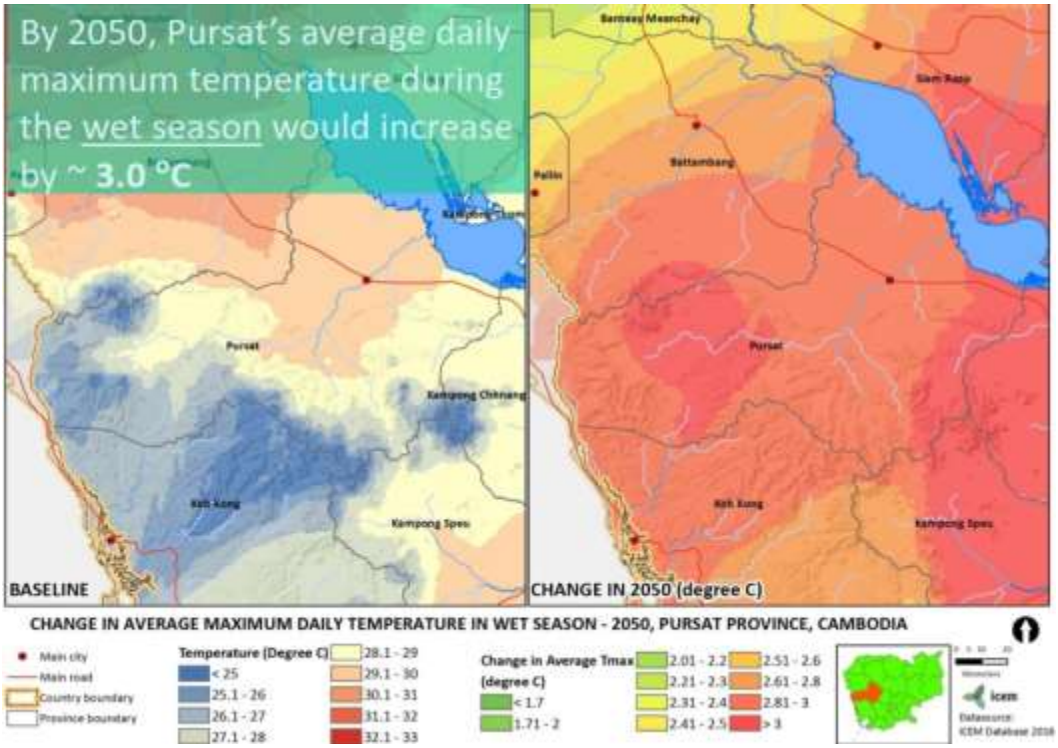


Figure 13-9 Changes in Temperatures in Wet Season

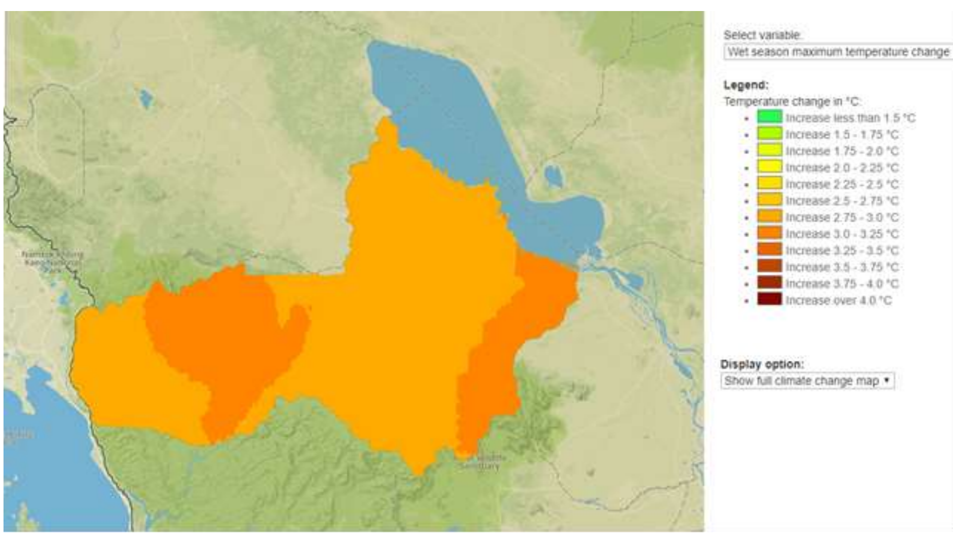


Figure 13-10 Wet Season Maximum Temperature Change

13.4.4. Dry season temperature

By 2050, the average daily max temperature in Pursat in the dry season would increase by about 2.2^{0}C.

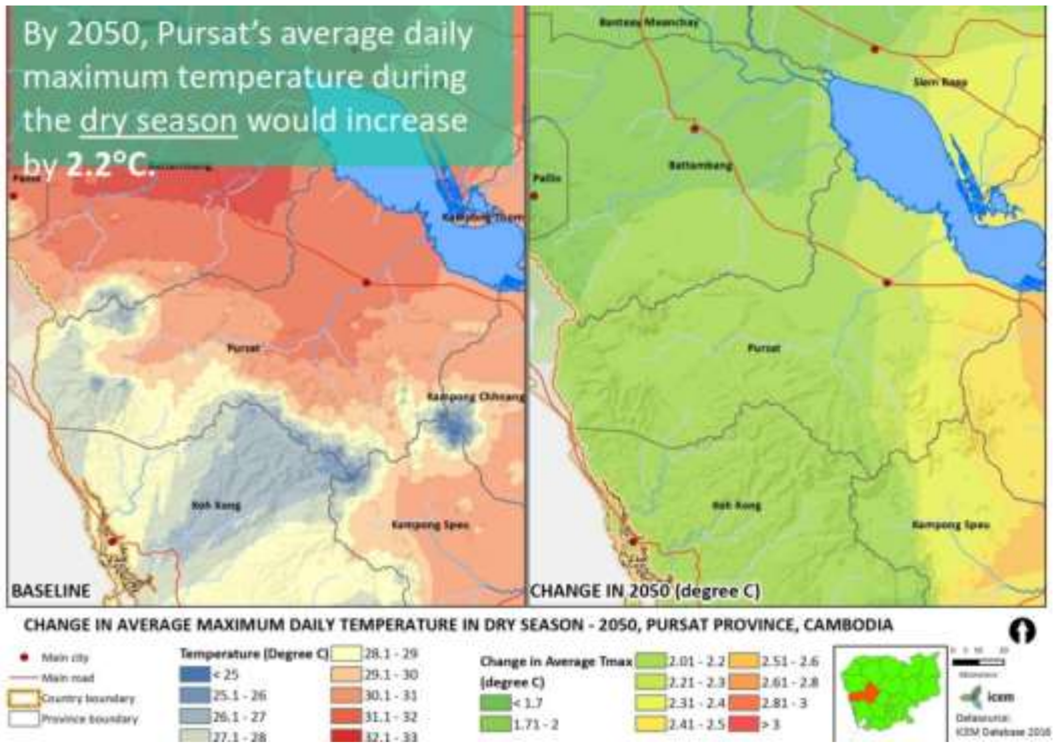


Figure 13-11 Changes in Temperatures in Dry Season

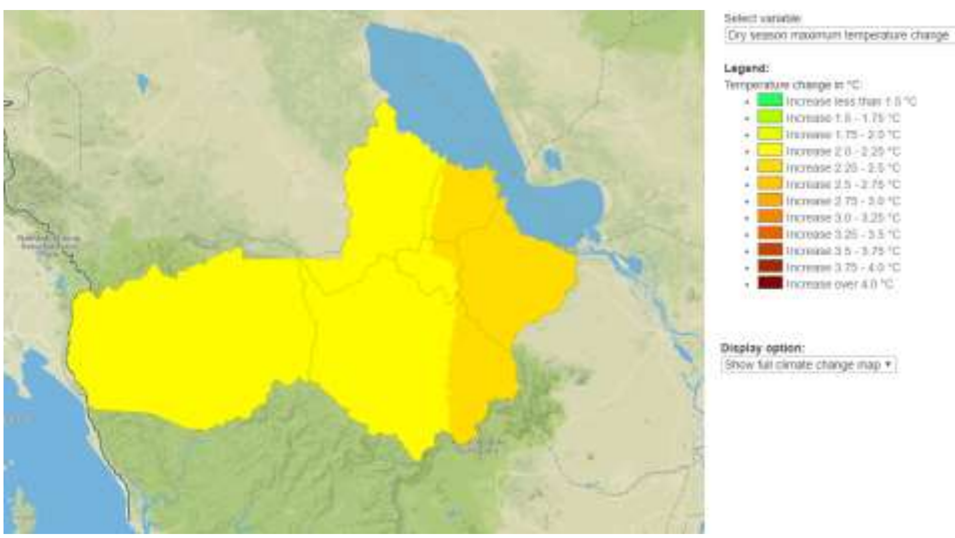


Figure 13-12 Dry Season Maximum Temperature Change

Table 13-2 Climate Change by District

Detailed climate change data by district:

No.	District	Maximum temperature (°C)						Precipitation (mm)					
		Dry season			Wet season			Dry season			Wet season		
		Baseline	2050	Changes	Baseline	2050	Changes	Baseline	2050	Changes	Baseline	2050	Changes
1	Bakan	31.6	33.8	2.2	29.8	32.7	2.9	254	254	-0.2%	1084	1165	7.5%
2	Kandieng	31.4	33.7	2.3	29.6	32.5	2.9	254	253	-0.3%	1078	1158	7.5%
3	Krakor	30.6	33	2.4	28.8	31.8	3	255	253	-1%	1087	1172	7.8%
4	Phnum Kravanh	29.8	32	2.2	28	31	3	263	262	-0.4%	1140	1229	7.8%
5	Pousat	31.2	33.4	2.2	29.3	32.3	3	256	255	-0.1%	1083	1164	7.4%
6	Veal Veaeng	28.8	31	2.1	26.9	29.9	3	313	312	-0.3%	1535	1647	7.3%

Total: 6 districts

13.4.5. Pursat Floods

Pursat will be significantly hotter and wetter in the wet season with increased severity of pluvial flooding (where flooding already occurs); potentially new areas of pluvial flooding; increased flows of the Mekong River; and floods would be deeper and longer.

Figure 13-13 Pursat 2011 Floods

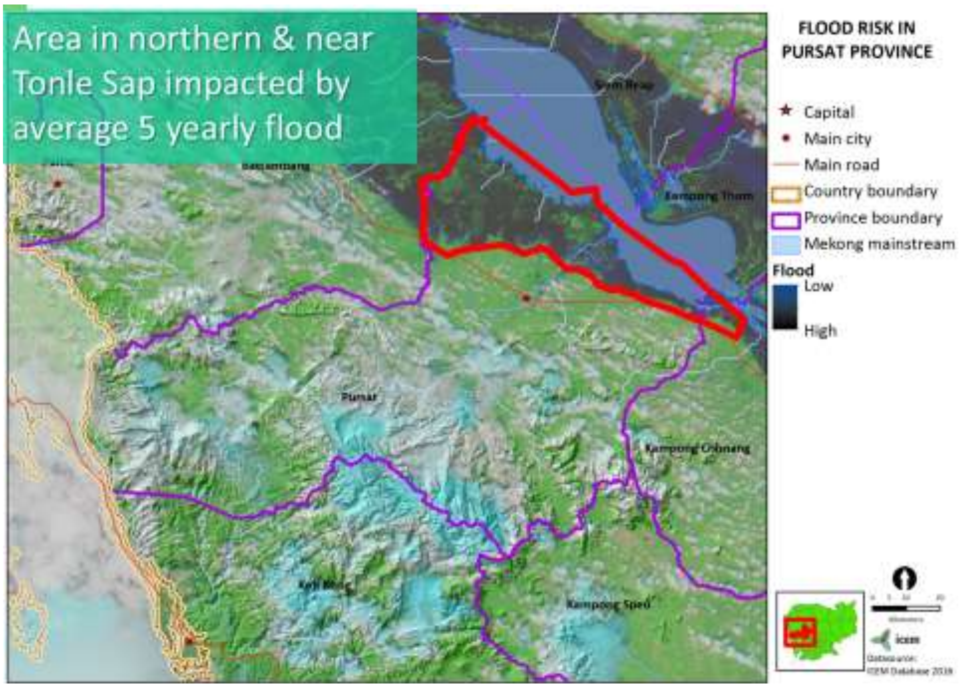


Figure 13-14 Pursat Flood Risk

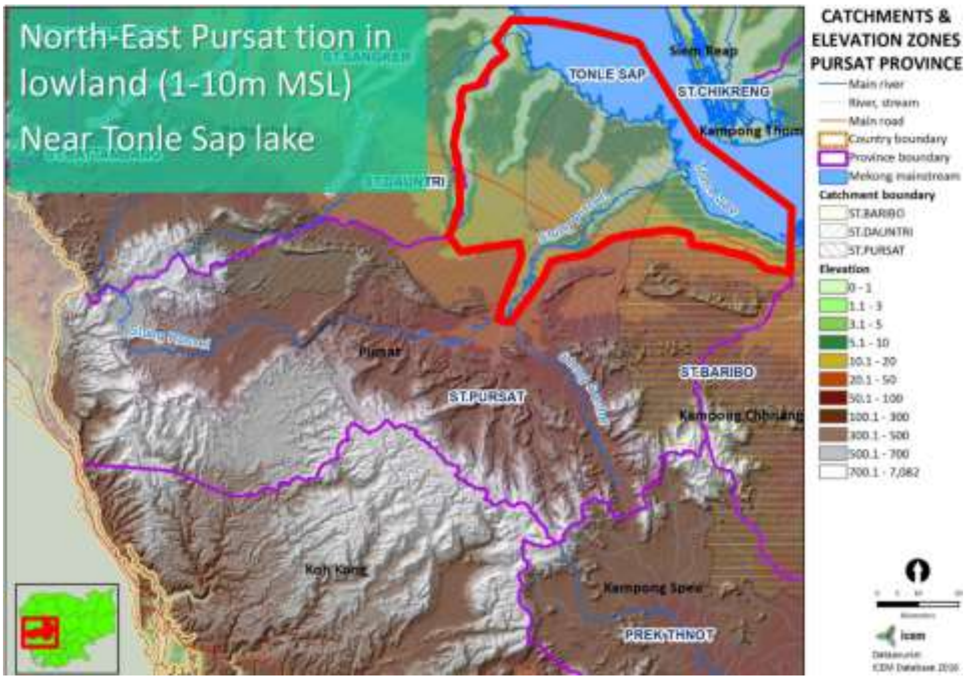


Figure 13-15 Pursat Catchments

13.4.1. Pursat Drought

Pursat will be significantly hotter and slightly dryer in the dry season with heat-related stress on infrastructure, agriculture and health; higher evaporation and lower rainfall may give increased incidence and duration of drought; and this may cause water stress for agriculture & domestic use.

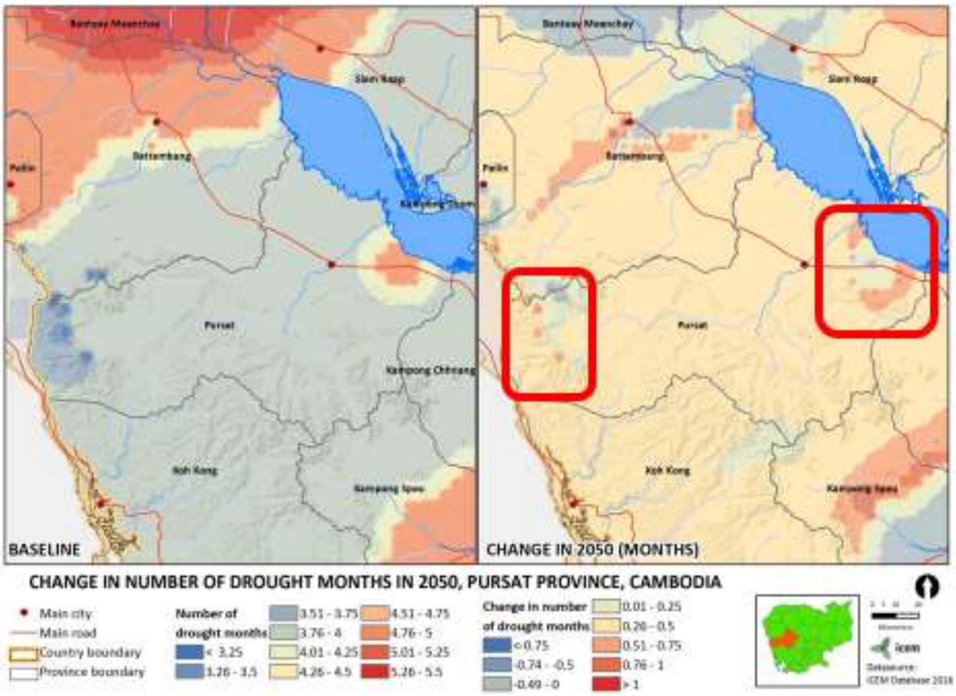


Figure 13-16 Pursat Drought Months

13.5. FRMI Climate Change Risks

196. The flood risk map for Pursat Province is shown below.

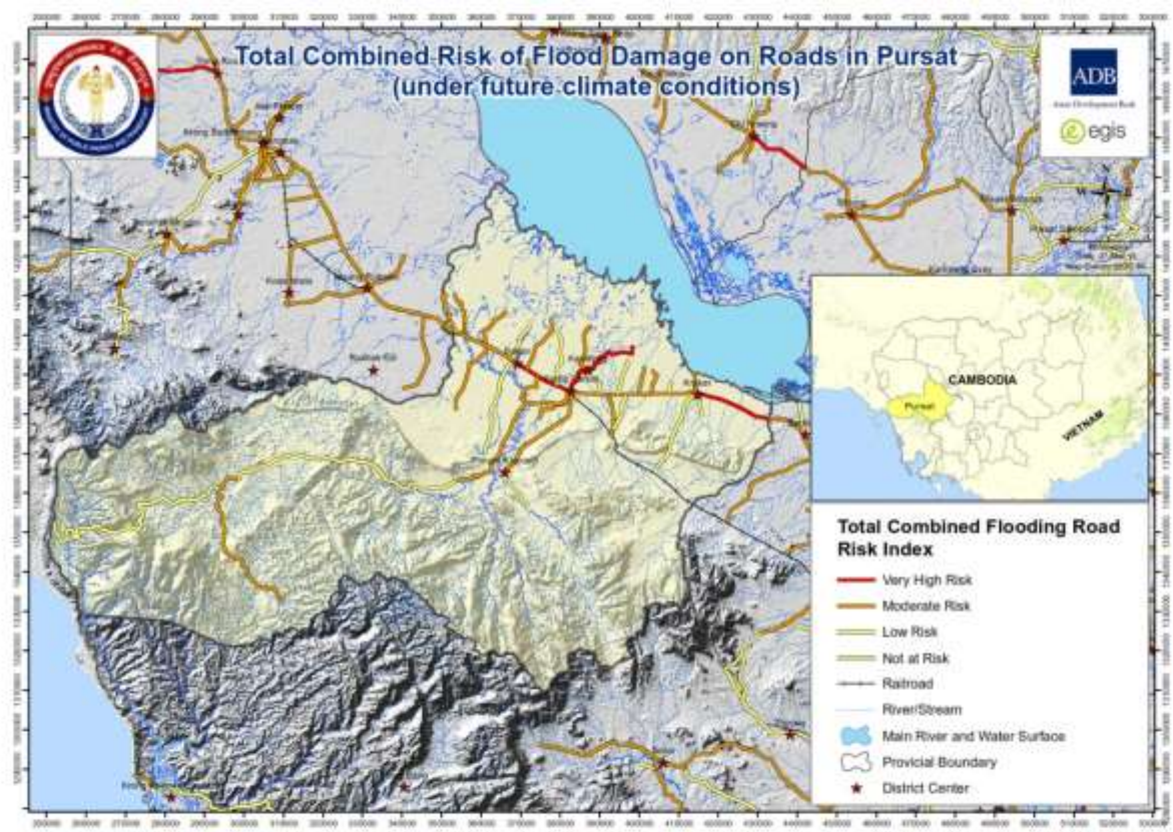


Figure 13-17 FRMI Flood Risk Map Pursat Province

197. Pursat is classified as being at **Moderate to Very High Risk** of flooding.

13.6. Rainfall Intensity-Duration-Frequency (IDF) Curves for Pursat Province

Table 13-3 Pursat IDF

Duration t		Intensity-Duration-Frequency (mm/hrs) Pursat								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	143	166	181	192	224	255	265	268	295
10	min	117	136	148	157	183	208	216	222	244
15	min	99	115	125	133	155	177	183	190	209
30	min	69.2	80	87	93	108	123	128	135	148
1	h	44.2	51.3	55.8	59.2	69	79	82	87	96
2	h	26.5	30.7	33.5	35.5	41.4	47.2	49.0	52.9	58.3
4	h	15.3	17.7	19.3	20.5	23.9	27.2	28.2	30.8	33.9
8	h	8.6	10.0	10.9	11.5	13.5	15.3	15.9	17.5	19.3
12	h	6.1	7.1	7.7	8.2	9.6	10.9	11.3	12.5	13.8
18	h	4.3	5.0	5.5	5.8	6.8	7.7	8.0	8.9	9.8
24	h	3.4	4.0	4.3	4.6	5.3	6.1	6.3	7.0	7.7

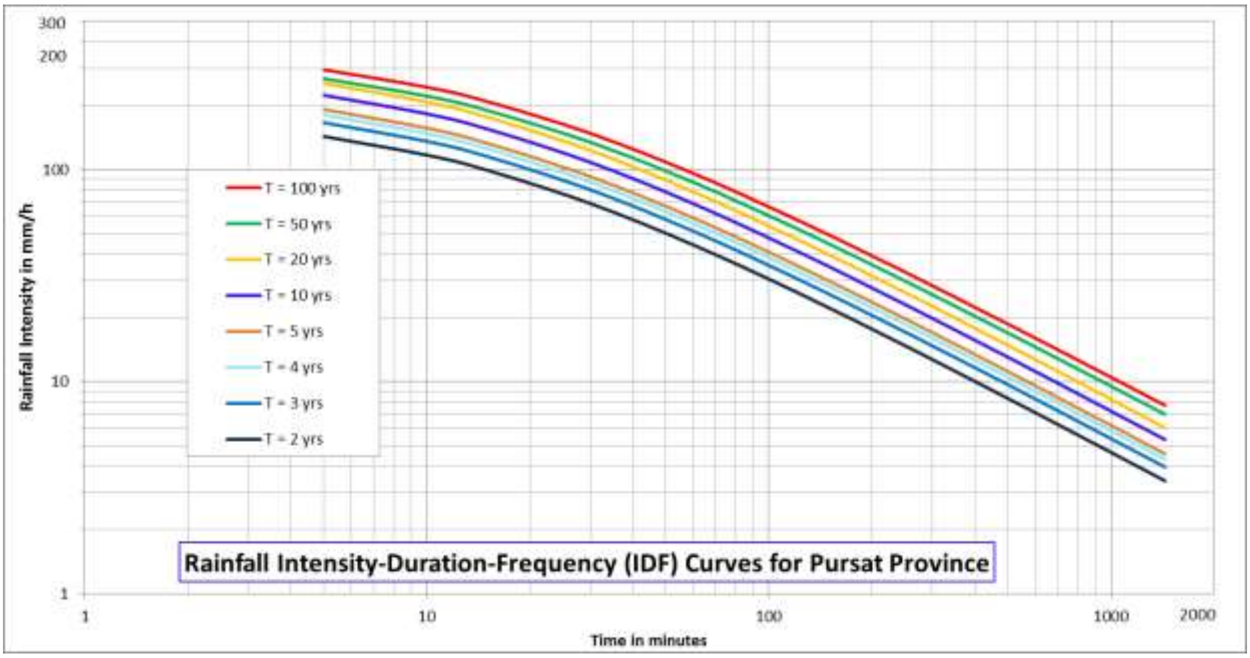


Figure 13-18 Pursat IDF

14. BATTAMBANG, BATTAMBANG PROVINCE

14.1. Location

Battambang is located in an area where water demands exceed available resources. The city of Battambang requires a raw water supply of at least 50,000m^3/day. The off-take point is downstream of the Kanghot irrigation scheme which provides local rice farmers with irrigation water. There is no clear agreement between national and level administration on which takes priority, water for agricultural irrigation or potable water supply for human consumption.

198. Further upstream of Kangkot Irrigation dam at a distance of 35kms is the Sek Sak Reservoir. This has a newly constructed 60 metre high rockfill dam and has a capacity of 280 million cubic metres. It contains a 13MW hydroelectric scheme.

199. It is still undergoing commissioning trials which may take 2 years to complete. MOWRAM are reluctant to give guaranteed discharge figures until the integrity of the dam and its backfilled reservoir are firmly established. Their position is that water will be supplied if available if the needs of the hydroelectric station and the minimum ecological flow have been satisfied.

200. Downstream of Battambang town point is another water supply scheme to be funded under Korean financing. This is the Sala Ta On spillway which is 7kms downstream of Battambang. No details are available of the off-take requirements.

Figure 14-1 Location Battambang

14.2. Rainfall

Rainfall data for Battambang is given below.

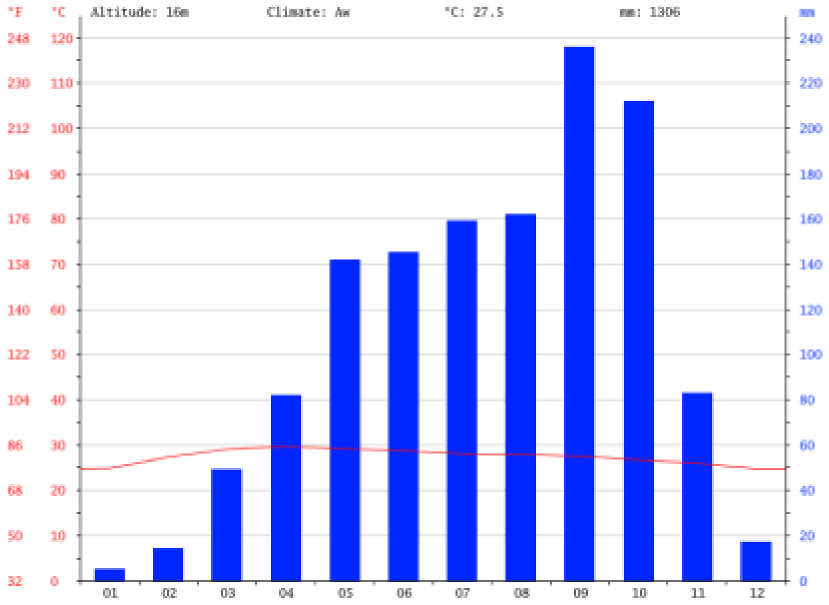


Figure 14-2 Climatograph Battambang

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	24.9	27.3	29	29.6	29.1	28.7	28	27.8	27.5	26.7	26	24.8
Min. Temperature (°C)	19.2	21.3	23.1	24	24.5	24.6	24.3	24.1	24	23.4	22	19.7
Max. Temperature (°C)	30.6	33.3	34.9	35.3	33.8	32.8	31.7	31.6	31.1	30.1	30	30
Avg. Temperature (°F)	76.8	81.1	84.2	85.3	84.4	83.7	82.4	82.0	81.5	80.1	78.8	76.6
Min. Temperature (°F)	66.6	70.3	73.6	75.2	76.1	76.3	75.7	75.4	75.2	74.1	71.6	67.5
Max. Temperature (°F)	87.1	91.9	94.8	95.5	92.8	91.0	89.1	88.9	88.0	86.2	86.0	86.0
Precipitation / Rainfall (mm)	5	14	49	82	142	145	159	162	236	212	83	17

Figure 14-3 Monthly Climate Battambang

The difference in precipitation between the driest month and the wettest month is 231 mm. The average temperatures vary during the year by 4.8 °C.

14.3. Climate Change Threat profile Battambang Province

The Battambang Province Climate Change threat profile is given below:

Table 14-1 Projected changes to average rainfall & maximum temperatures by 2050:

Climate change parameter	Baseline	With C.C.	Change
Average annual rainfall:	1300 mm	1365 mm	+5 %
Total rainfall in wet season:	1318 mm	1419 mm	+7.7 %
Total rainfall in dry season (Nov - Apr):	269 mm	267 mm	-0.4 %
Average daily maximum temperature (Annual)	31.4 °C	33.7 °C	+2.3 °C
Average maximum temperature in wet season:	30.6 °C	33.3 °C	+2.7 °C
Average maximum temperature in dry season:	32.2 °C	34.1 °C	+1.9 °C

14.4. Projected changes to average rainfall & maximum temperatures by 2050

14.4.1. Wet season rainfall

By 2050, total rainfall in the wet season in Battambang would increase about 7.7%.

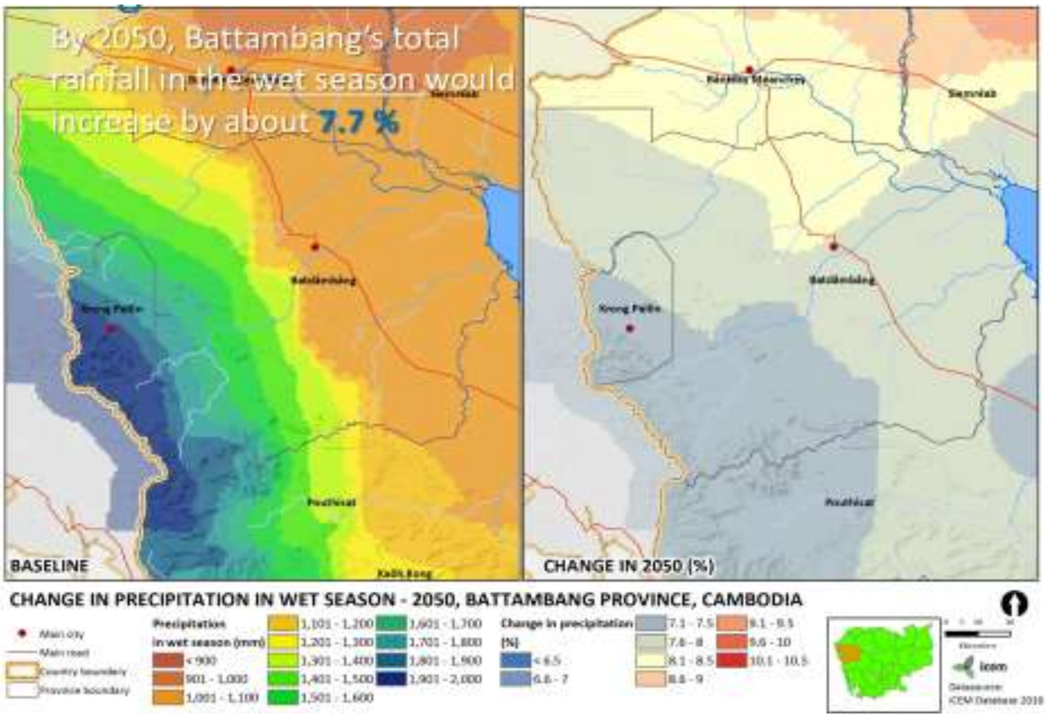


Figure 14-4 Battambang Wet season Rainfall

14.4.2. Dry season rainfall

By 2050, total rainfall in Battambang in the dry season would decrease about -0.4%.

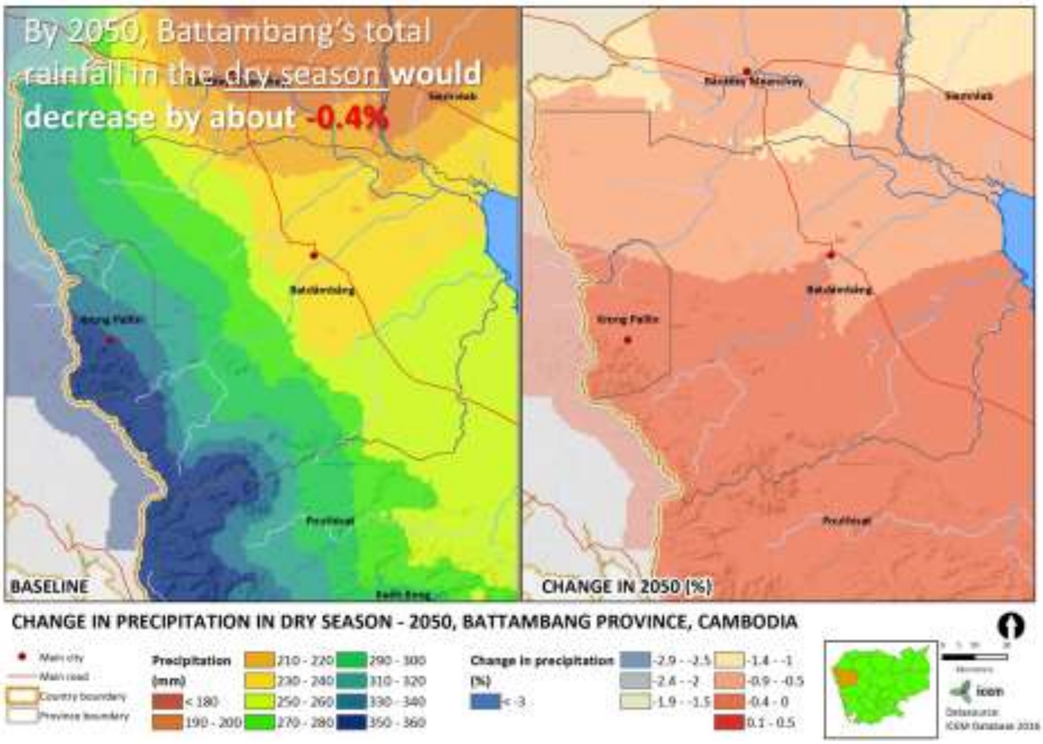


Figure 14-5 Battambang Dry season Rainfall

14.4.3. Wet season temperature

By 2050, the average daily maximum temperature in Battambang in the wet season would increase by about 3.0 ^{0}C.

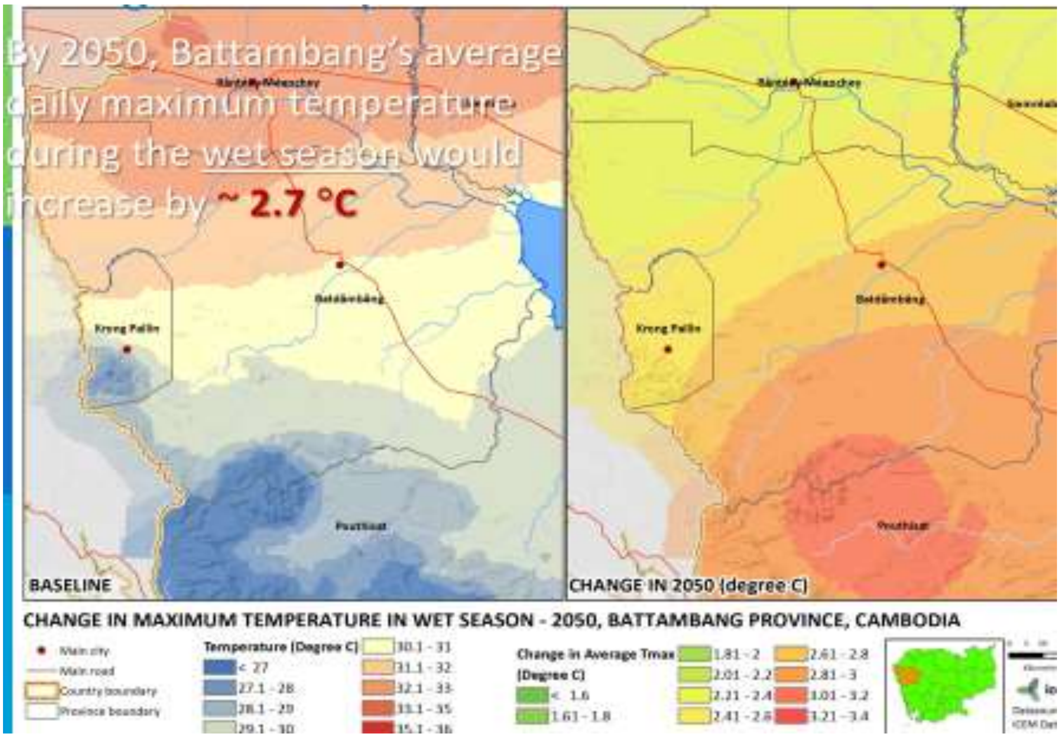


Figure 14-6   Battambang Wet season Temperatures

14.4.4. Dry season temperature

By 2050, the average daily max temperature in Battambang in the dry season would increase by about 1.9 ^{0}C.

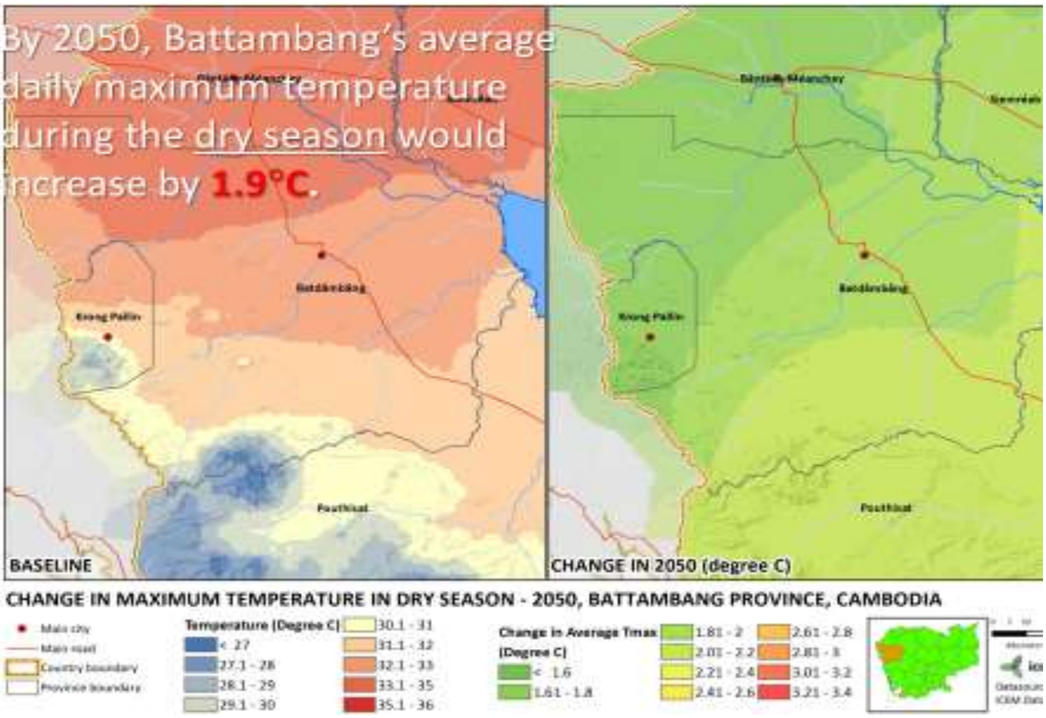


Figure 14-7   Battambang Dry season Temperatures

14.4.1.   Battambang Floods

Battambang is located in a significant catchment area and one must consider rainfall in the entire catchments to ascertain effects for the city centre.

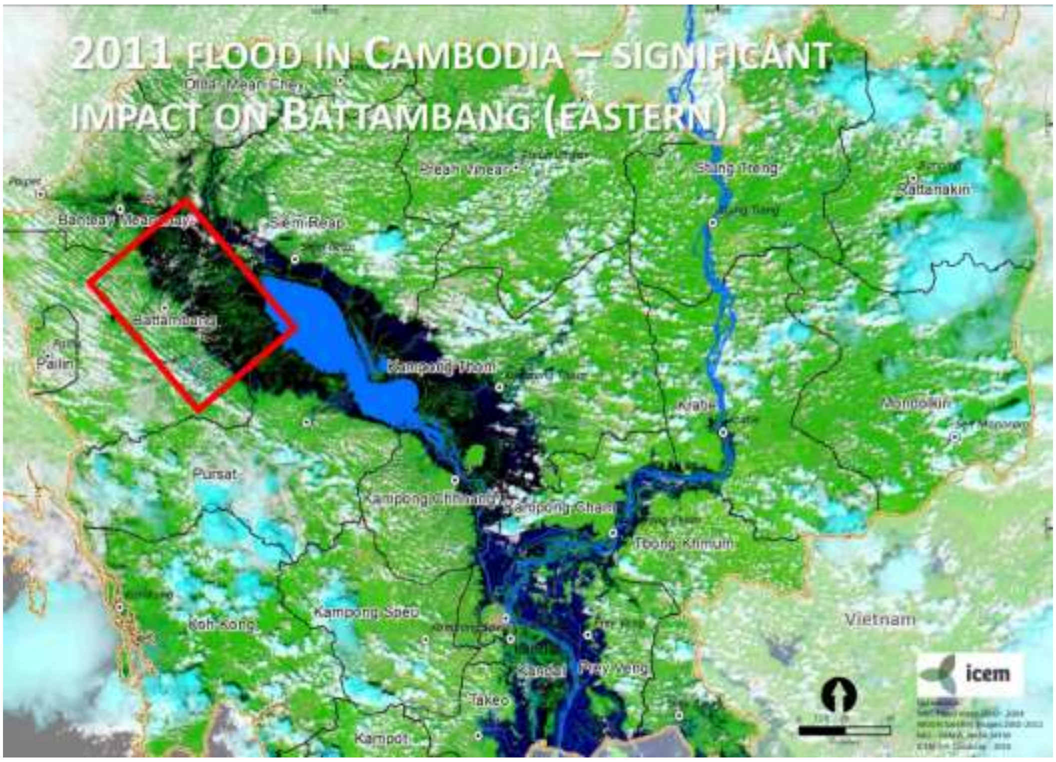


Figure 14-8　　Battambang Floods 2011

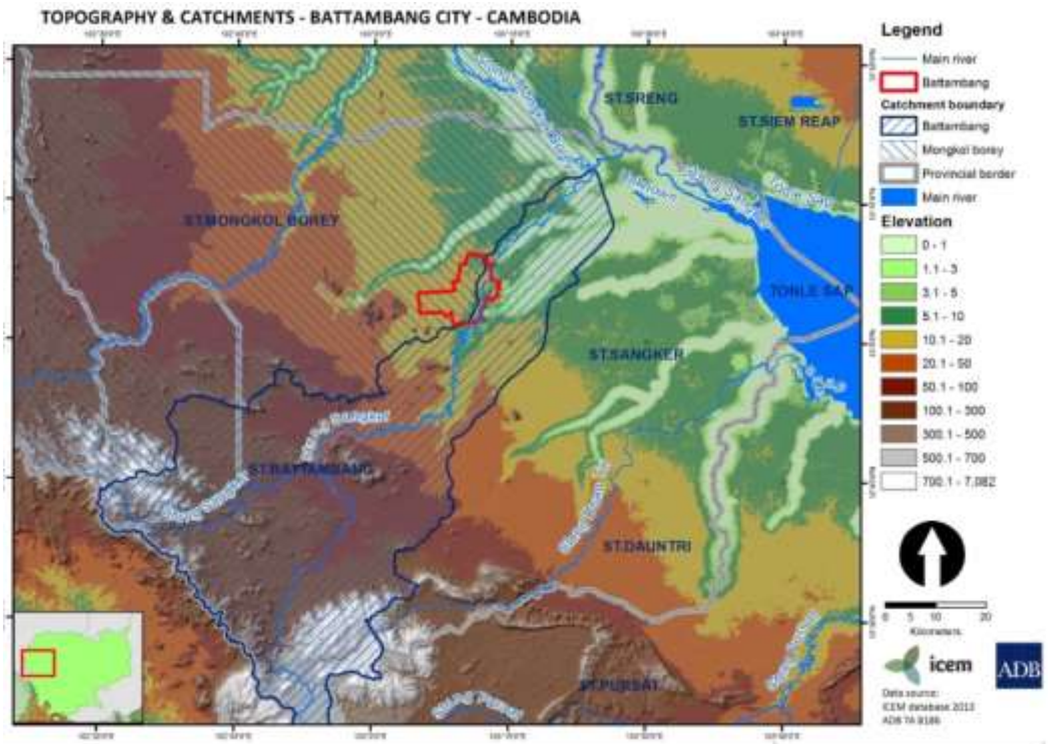


Figure 14-9　　Battambang Watersheds

It is estimated that discharges from catchments would increase by 16% by 2050 due to climate change.

Watershed	Annual rainfall		Rainfall in dry season		Rainfall in wet season		Ave discharge in dry season		Ave discharge in wet season		Max discharge	
	BL	In 2050	BL	In 2050	BL	In 2050	BL	In 2050	BL	In 2050	BL	In 2050
	mm	mm	mm	mm	mm	mm	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s
West	1554	1654	257	255	1297	1399	3	3	24	25	366	390
Upper	**2009**	**2134**	**312**	**312**	**1697**	**1822**	**2**	**2**	**17**	**17**	**181**	**215**
Lower	1275	1356	229	228	1046	1128	7	7	46	47	561	643

Figure 14-10 Battambang Watershed Flows

14.4.1. Battambang Drought

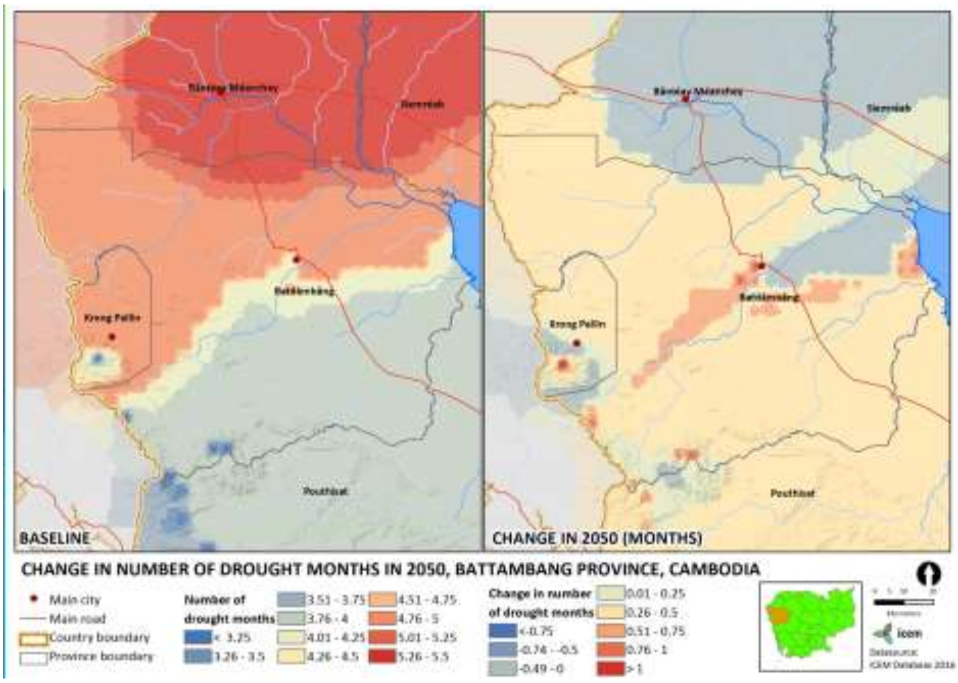


Figure 14-11 Battambang Drought Months

14.5. FRMI Climate Change Risks

201. The flood risk map for Battambang Province is shown below.

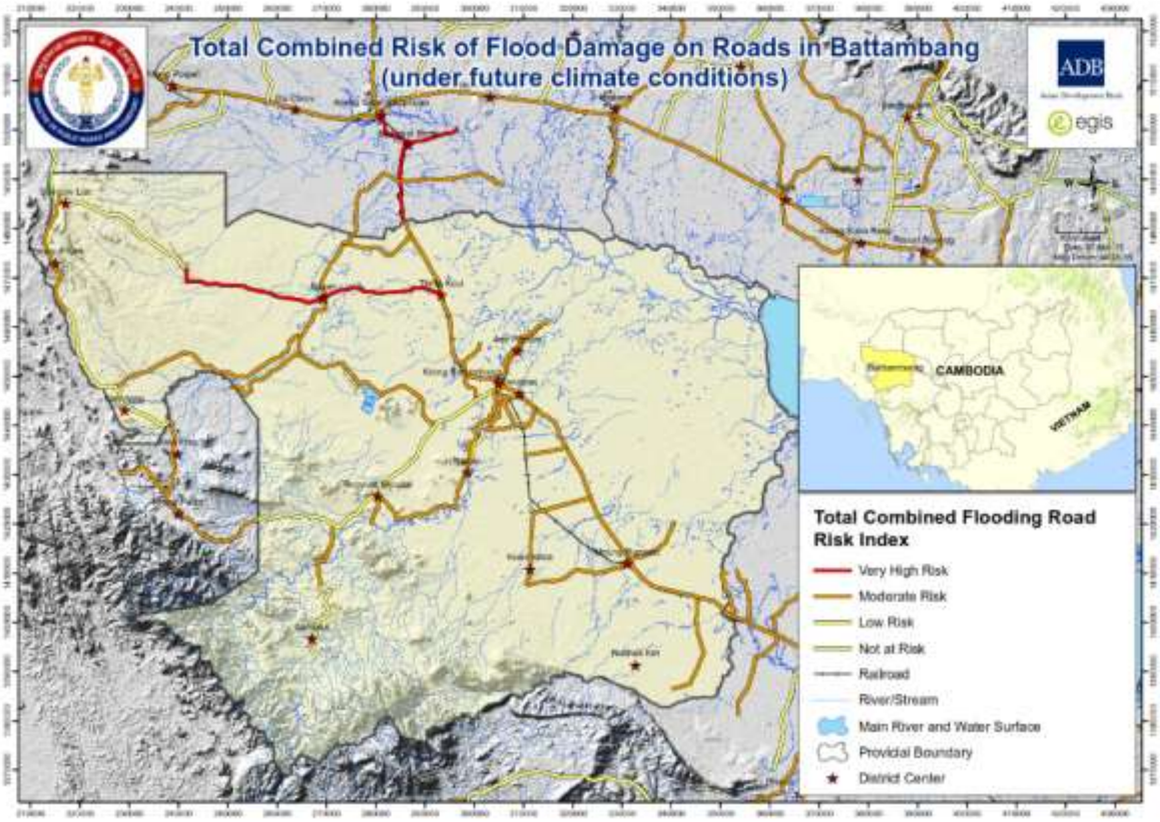


Figure 14-12 FRMI Flood Risk Map Battambang

202. Battambang city is classified as being at **Moderate Risk** of flooding with areas to the north west being classified as being at **High Risk** of flooding.

14.6. Rainfall Intensity-Duration-Frequency (IDF) Curves for Battambang Province

Table 14-2 Battambang IDF

Duration		**Intensity-Duration-Frequency (mm/hrs)** Battambang								
		Return Period, T								
		2	**3**	**4**	**5**	**10**	**20**	**25**	**50**	**100**
5	min	141	157	167	175	197	218	225	223	242
10	min	115	128	136	143	161	178	183	185	200
15	min	98	109	116	121	136	151	156	158	171
30	min	68.2	76	81	84	95	105	109	112	121
1	h	43.6	48.4	51.6	53.9	61	67	69	73	79
2	h	26.1	29.0	30.9	32.3	36.4	40.3	41.6	44.0	47.7
4	h	15.1	16.7	17.8	18.6	21.0	23.2	24.0	25.6	27.8
8	h	8.5	9.4	10.1	10.5	11.8	13.1	13.5	14.6	15.8
12	h	6.0	6.7	7.2	7.5	8.4	9.3	9.6	10.4	11.3
18	h	4.3	4.8	5.1	5.3	6.0	6.6	6.8	7.4	8.1
24	h	3.4	3.7	4.0	4.2	4.7	5.2	5.3	5.8	6.3

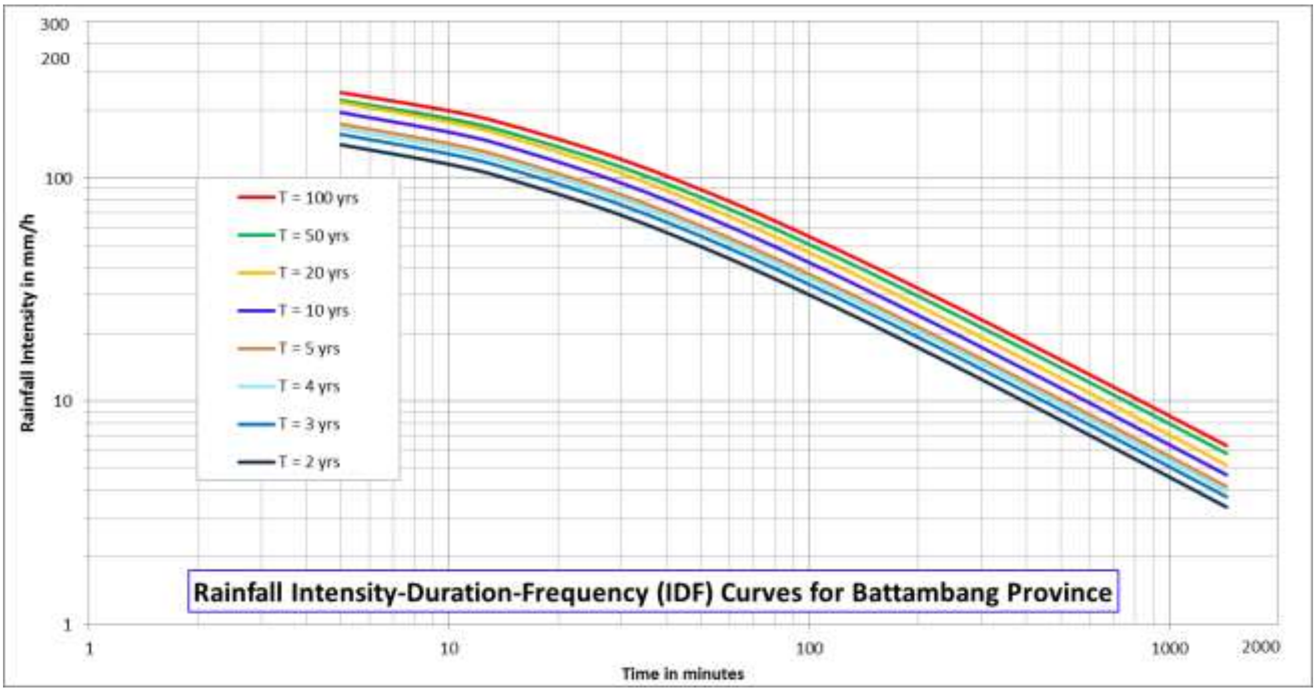


Figure 14-13 Battambang IDF

15. SEREI SAOPHOAN, BANTEAY MEANCHEY PROVINCE

15.1. Location

Serei Saophoan is located in the province Banteay Meanchey northwest of the Tonle Sap Lake surrounded by the provinces Oddar Meachey (northeast), Seam Reap (east), Battambang (south) and borders with Thailand (west, northwest).

The topography around Serei Saophoan municipality is characterized by flat, low lying land, ranging between 10 and 20 m above sea level. A major feature of Serei Saophoan is the Saphon River, which flows south along the municipality.

The location is influenced by floods from Thailand and run off from rainfall on the Dangrek escarpment to the north.

Figure 15-1 Location Serei Sisophon

15.2. Rainfall

Serei Saophoan has two seasons, dry season from November until April and wet season from May to October with regular monsoon events.

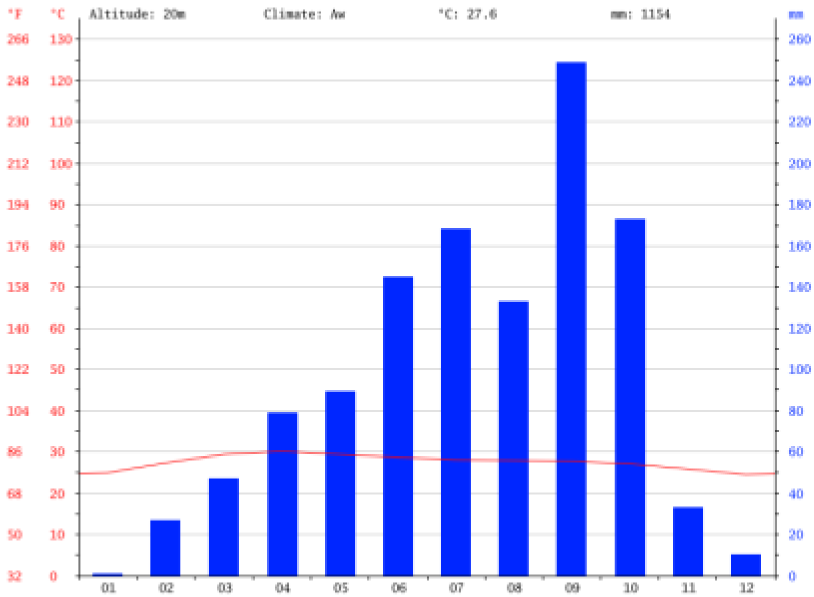
Table 15-1 Average and mean rainfall data over years (1989-2016)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	1	2	3	4	5	6	7	8	9	10	11	12	[mm]
Average	6,25	17,0	33,9	109,0	129,2	143,2	150,0	168,1	230,7	181,6	36,8	4,7	**1.211**
Min	0	0	0	29	37,2	37	31	42,1	69,9	19,3	0	0	**581**
Max	38,3	71,7	100,4	396,4	286,3	284,3	328,6	298,6	457,5	346,7	145	53,8	**1.618**
Mean	19,15	35,85	50,2	212,7	161,75	160,65	179,8	170,35	263,7	183	72,5	26,9	**1.099**

The average rainfall is 1,200 mm with peak measures in September/October and lowest values in December/January. Yearly rainfalls below 1,000 mm are marked as dry years, while years with rainfall above 1,400 mm are prone to flooding.

Rainfall data for Banteay Meanchey is given below.

Table 15-2 Climatograph Banteay Meanchey



	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	25	27.4	29.4	30.1	29.4	28.7	28.1	28	27.8	27.2	25.9	24.6
Min. Temperature (°C)	18.5	21.1	23.3	24.3	24.5	24.3	24.1	24	24	23.3	21.1	18.8
Max. Temperature (°C)	31.5	33.8	35.5	35.9	34.4	33.1	32.1	32	31.6	31.1	30.7	30.5
Avg. Temperature (°F)	77.0	81.3	84.9	86.2	84.9	83.7	82.6	82.4	82.0	81.0	78.6	76.3
Min. Temperature (°F)	65.3	70.0	73.9	75.7	76.1	75.7	75.4	75.2	75.2	73.9	70.0	65.8
Max. Temperature (°F)	88.7	92.8	95.9	96.6	93.9	91.6	89.8	89.6	88.9	88.0	87.3	86.9
Precipitation / Rainfall (mm)	1	27	47	79	89	145	168	133	249	173	33	10

Figure 15-2 Monthly Climate Banteay Meanchey

The variation in the precipitation between the driest and wettest months is 248 mm. The variation in annual temperature is around 5.5 °C.

15.3. Climate Change Threat profile Banteay Meanchey Province

The Banteay Meanchey Province Climate Change threat profile is given below:

Table 15-3 Projected changes to average rainfall & maximum temperatures by 2050:

Climate change parameter	Baseline	With C.C.	Change
Average annual rainfall:	1245 mm	1332 mm	+6.9 %
Total rainfall in wet season:	1042 mm	1131 mm	+8.5 %
Total rainfall in dry season (Nov - Apr):	203 mm	201 mm	-0.9 %
Average daily maximum temperature (Annual)	33.3 °C	35.3 °C	+2.0 °C
Average maximum temperature in wet season:	32.7 °C	34.9 °C	+2.2 °C
Average maximum temperature in dry season:	33.9 °C	35.7 °C	+1.8 °C

15.3.1. Projected changes to average rainfall & maximum temperatures by 2050

15.3.2. Wet season rainfall

By 2050, total rainfall in Banteay Mean Chey in the wet season would increase by about 8.5%.

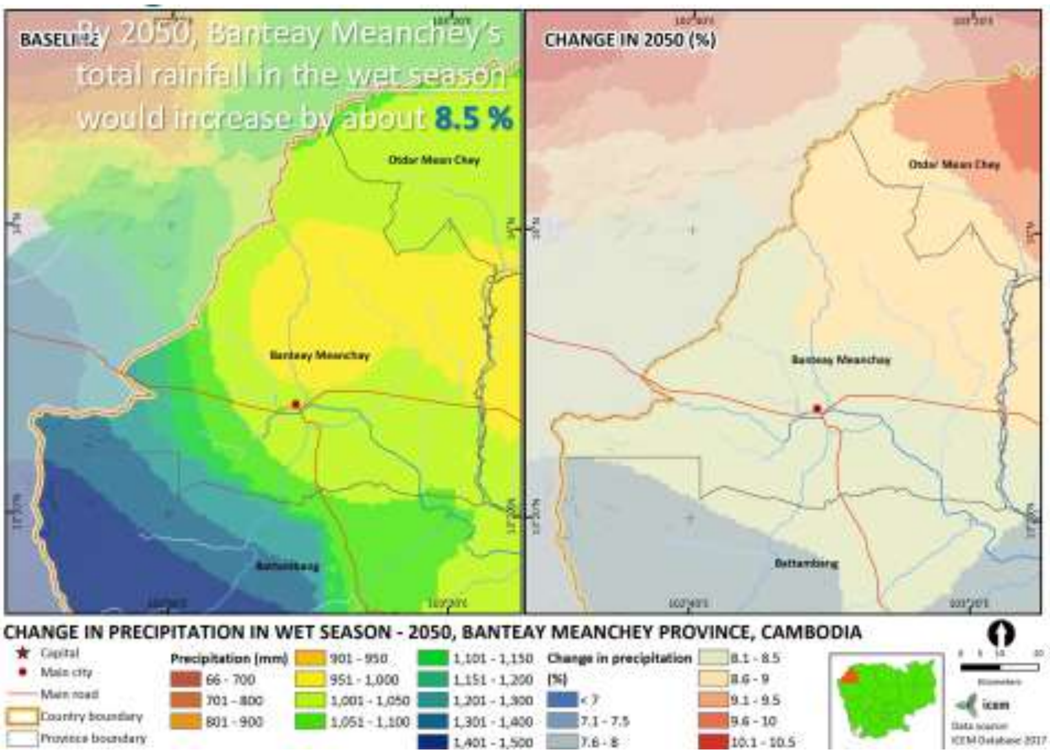


Figure 15-3 Serei Sisophon Wet Season Rainfall

15.3.3. Dry season rainfall

By 2050, total rainfall in Banteay Mean Chey in the dry season would decrease by about 0.9%.

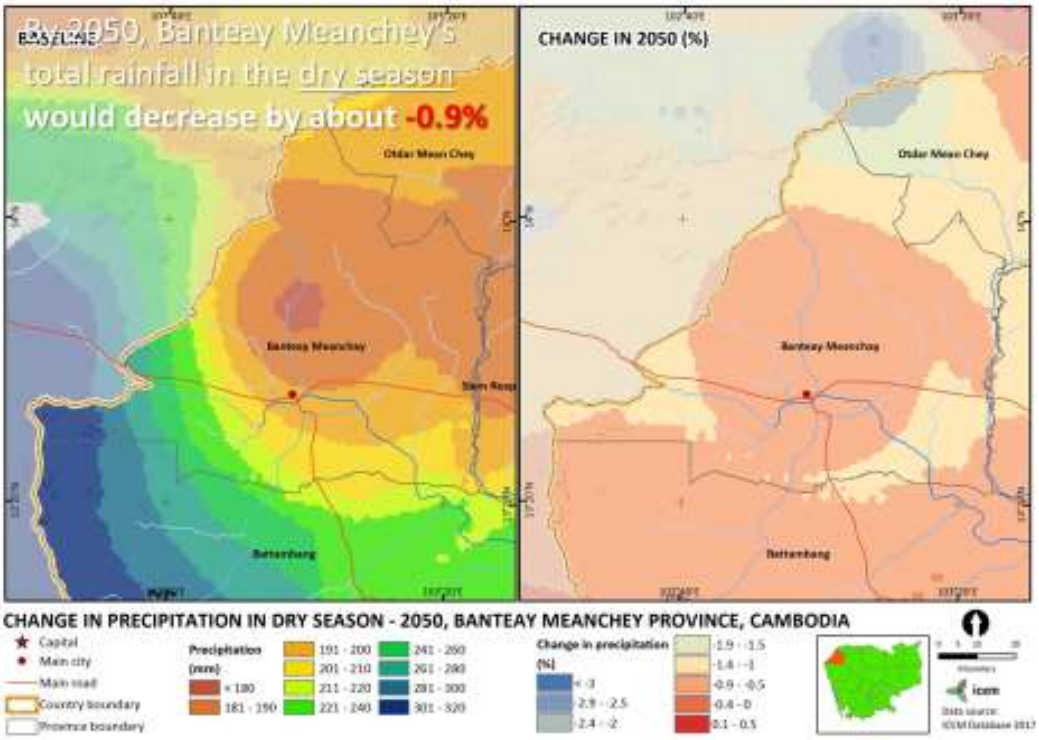


Figure 15-4 Serei Sisophon Dry Season Rainfall

15.3.4. Wet season temperature

By 2050, the average daily maximum temperature in Banteay Meanchey in the wet season would increase by about 2.7 ^{0}C.

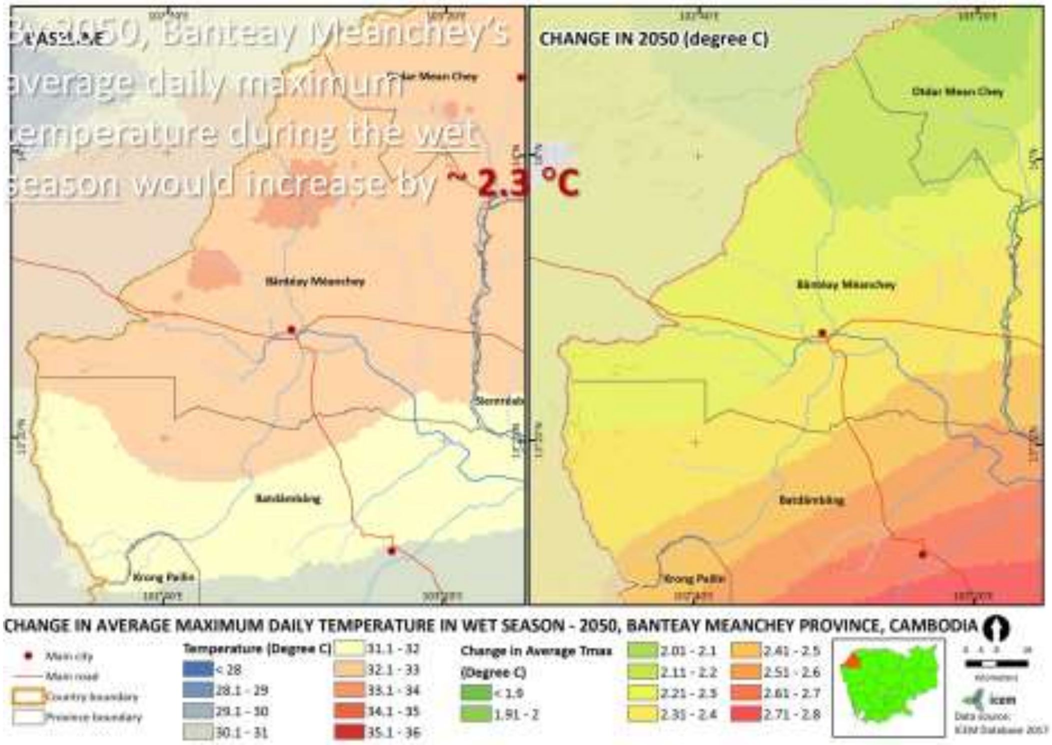


Figure 15-5 Serei Sisophon Wet Season Temperature

15.3.5. Dry season temperature

By 2050, the average daily max temperature in dry season would increase by about 1.8 ^{0}C.

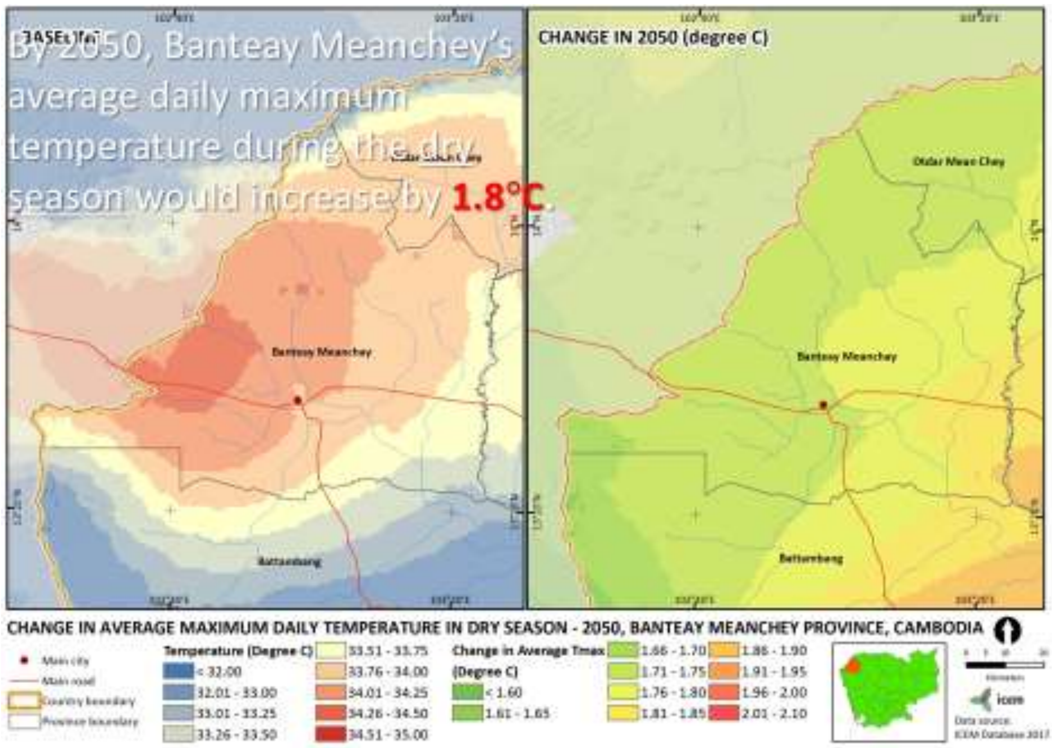


Figure 15-6 Serei Sisophon Dry Season Temperature

15.3.1. Banteay Meanchey Floods

In September 2012 some 11 people died from flooding in Banteay Meanchey province, due to flood waters that were between 1 and 3 meters deep in areas of Serei Saophoan. Almost 600 people were evacuated from their homes, over 47,000 hectares of rice paddy were lost in the province and more than 2,000 hectares of other crops damaged.

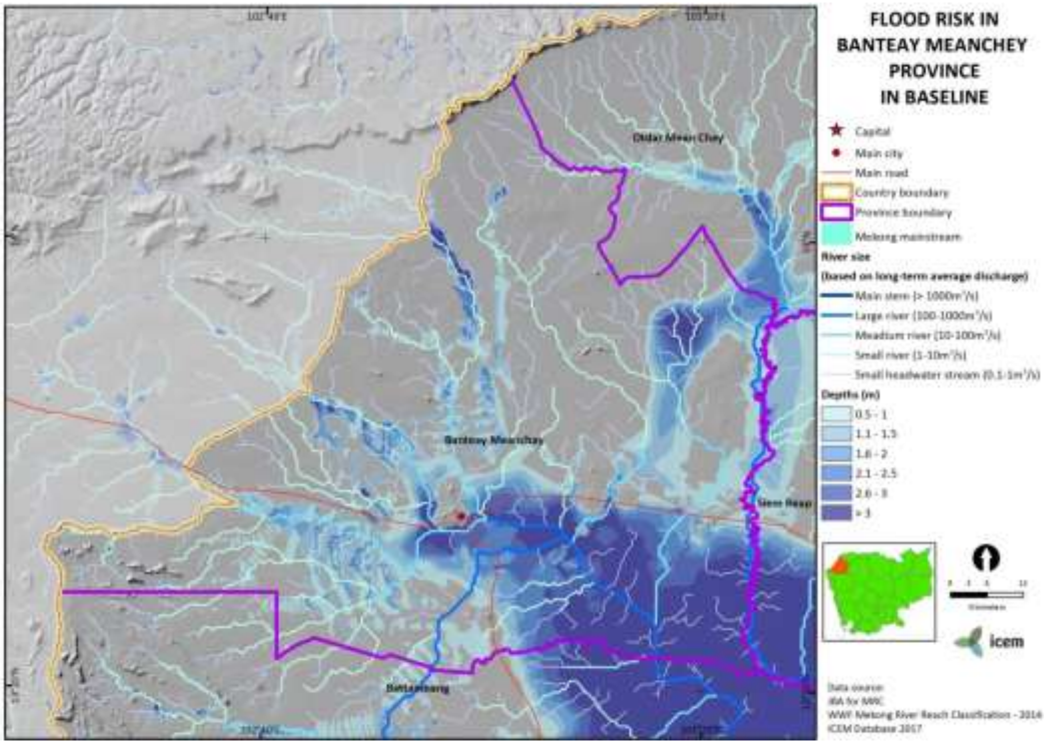


Figure 15-7 Serei Sisophon Current Flood Risks

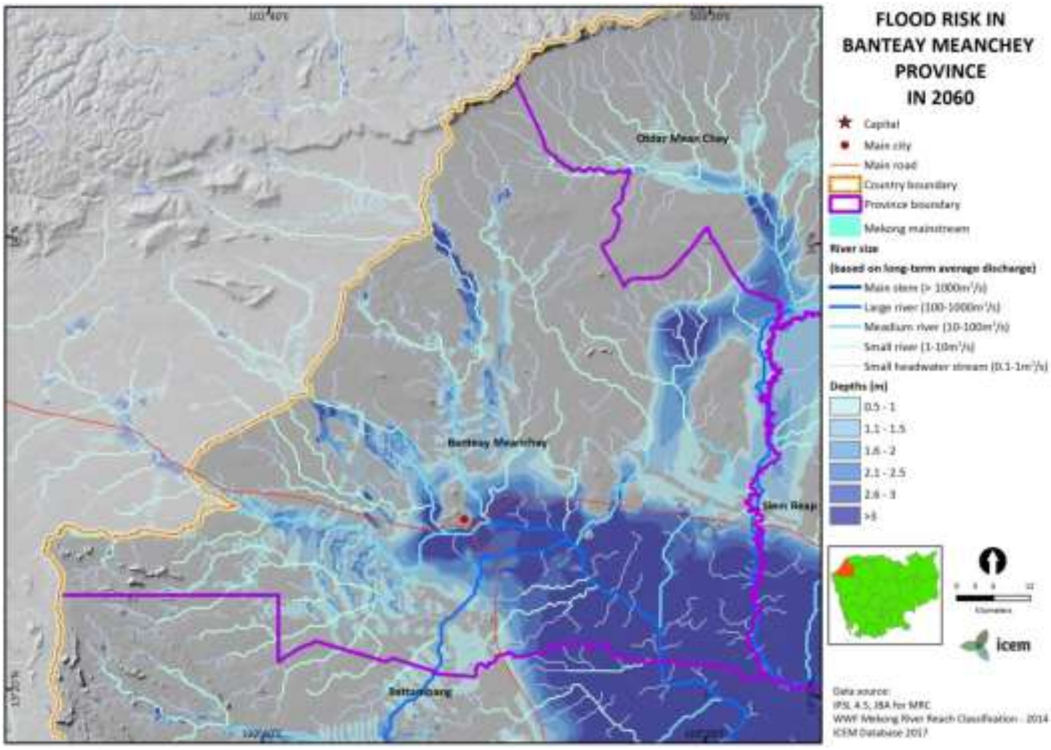


Figure 15-8 Serei Sisophon Future Flood Risks

15.3.1. Banteay Meanchey Drought

Banteay Meanchey is expected to be significantly hotter and much wetter in the wet season and significantly hotter and slightly dryer in the dry season. On occasion the Saophoan river has run dry.

In 2015 Trapaing Thmor reservoir, which is also a well known bird sanctuary, and which normally holds 180 million cubic meters of water only held 25 million cubic meters, farmers were struggling to save crops due to a drought brought on by El Nino, and over 50,000 hectares of crops were damaged in five provinces including Banteay Meanchey.

15.4. FRMI Climate Change Risks

203. The flood risk map for Banteay Meanchey Province is shown below.

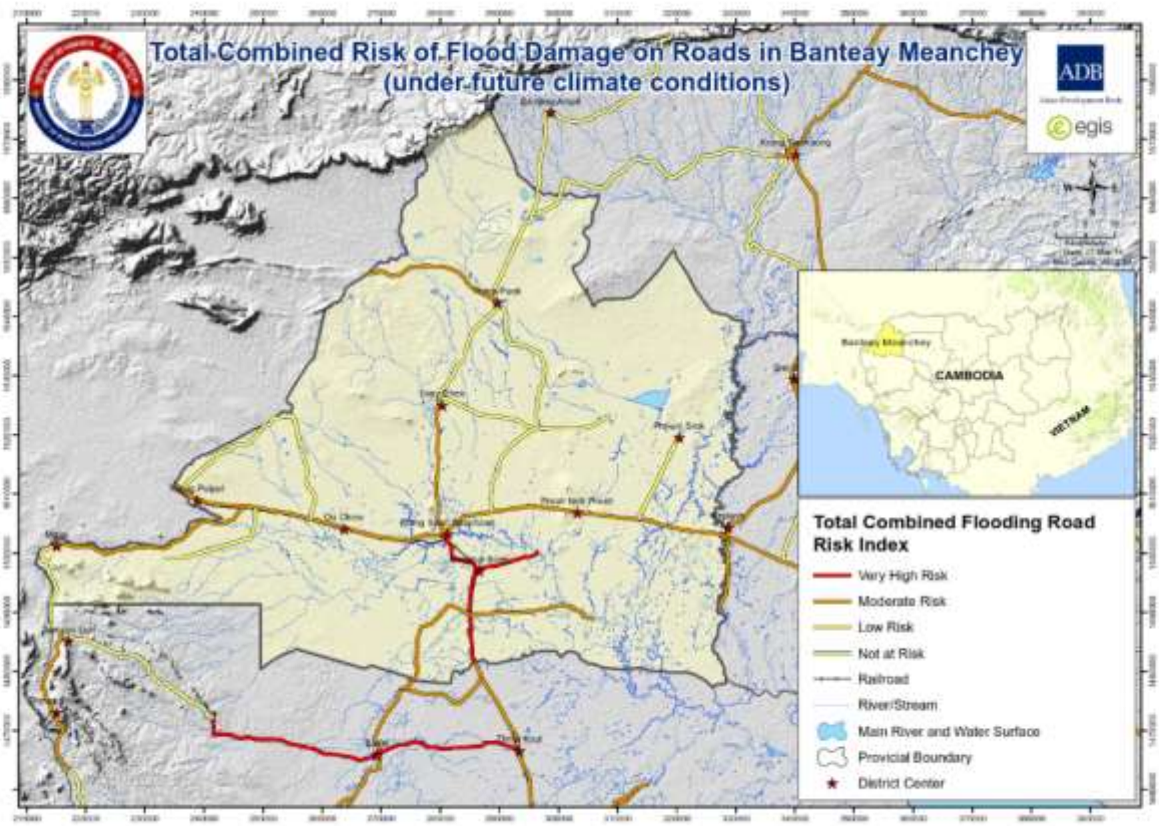


Figure 15-9 FRMI Flood Risk Map Banteay Meanchey Province

204. The area in the city and to the north are classified as being at **Moderate Risk** of flooding and the areas to the south of the city are classified as being at **Very High Risk** of flooding due to the influence of Tonle Sap Lake.

15.5. Rainfall Intensity-Duration-Frequency (IDF) Curves for Banteay Meanchey Province

Table 15-4 Banteay Meanchey IDF

Duration t		**Intensity-Duration-Frequency (mm/hrs)** Banteay Meanchey								
		Return Period, T								
		2	**3**	**4**	**5**	**10**	**20**	**25**	**50**	**100**
5	min	140	156	167	174	197	219	225	224	243
10	min	114	128	136	142	161	178	184	185	201
15	min	97	108	115	121	136	151	156	159	172
30	min	67.7	75	80	84	95	106	109	113	122
1	h	43.2	48.2	51.4	53.7	61	67	70	73	79
2	h	25.9	28.9	30.8	32.2	36.4	40.4	41.7	44.2	48.0
4	h	14.9	16.7	17.8	18.6	21.0	23.3	24.0	25.8	28.0
8	h	8.4	9.4	10.0	10.5	11.8	13.1	13.6	14.7	15.9
12	h	6.0	6.7	7.1	7.5	8.4	9.4	9.6	10.5	11.4
18	h	4.3	4.7	5.1	5.3	6.0	6.6	6.8	7.5	8.1
24	h	3.3	3.7	4.0	4.1	4.7	5.2	5.4	5.9	6.4

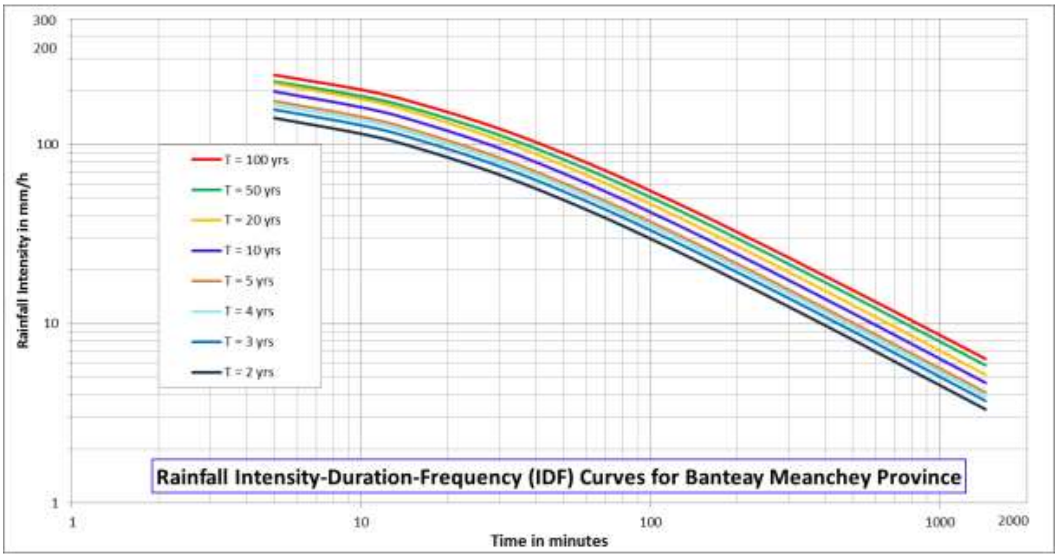


Figure 15-10 Banteay Meanchey IDF

16. SIEM REAP

16.1. Location

Siem Reap has a tropical climate with a dry and wet season. The dry season runs from November till April. During this period it is sunny, warm and humid with temperatures between 25-35ºC. The hottest month is April when the temperature may exceed 35ºC. In the hot and dry season there will be almost none or little rainfall.

In the monsoon or rainy season which runs from May till the end of October heavy rain showers can occur. At the beginning of the rainy season it is quite hot and rains most of the time only in the late afternoon or early morning. (This is also the start of the rice planting season.) June, July and August are cooler and rain will fall in the evenings and at night. September and October are the wettest months of the year and it may rain at any time.

Siem Reap is prone to flooding. The river flows through the heart of Siem Reap and can overflow during September or October. This is caused not only by heavy rainfall in the areas around Siem Reap but also by water coming from Phnom Kulen, a local high point of elevation 330masl, which flows to Tonle Sap Lake. In 2011 Siem Reap and Cambodia experienced the worst flood in fifty years. Many rice fields, roads and other public utilities were destroyed.

Figure 16-1 Location Siem Reap

Siem Reap is also influenced by runoff from the nearby Dangrek Escarpment which forms the border with Thailand.

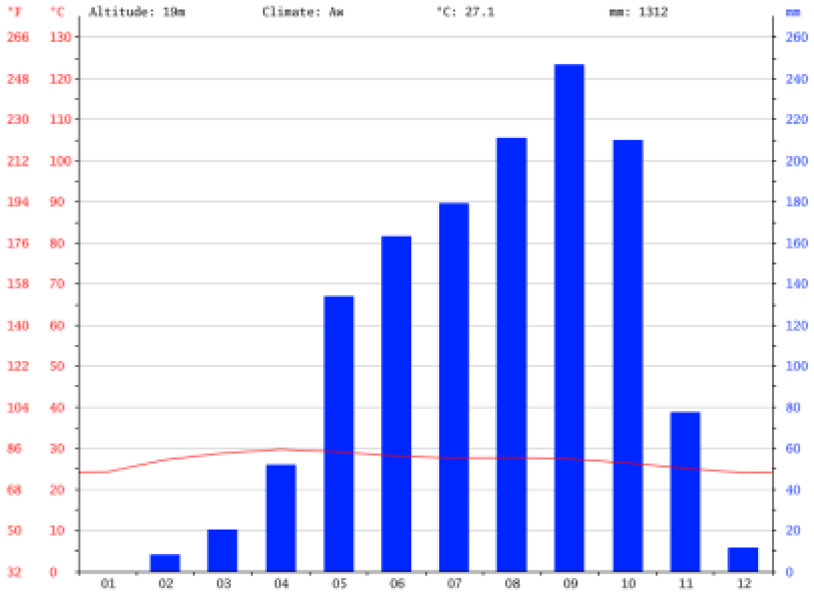
16.2. Rainfall

The table below gives an overview of the average temperature and rainfall of Siem Reap for the period 1997-2001.

April and May are the hottest months of the year with an average maximum temperature of 35°C. November, December and January are the coolest. Most of the rain falls during September and October. These two months have 21 days of rain which indicates that one can expect rainfall almost every day. December, January and February are very dry.

Rainfall data for Siem Reap is given below.

Table 16-1 Climatograph Siem Reap



	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	24.2	27.2	28.8	29.7	29.1	28.1	27.6	27.7	27.4	26.4	25.1	24
Min. Temperature (°C)	18.2	21.7	23.5	24.8	24.7	24.1	23.9	24	23.8	22.7	20.2	18.1
Max. Temperature (°C)	30.2	32.8	34.1	34.7	33.5	32.2	31.4	31.5	31.1	30.1	30.1	30
Avg. Temperature (°F)	75.6	81.0	83.8	85.5	84.4	82.6	81.7	81.9	81.3	79.5	77.2	75.2
Min. Temperature (°F)	64.8	71.1	74.3	76.6	76.5	75.4	75.0	75.2	74.8	72.9	68.4	64.6
Max. Temperature (°F)	86.4	91.0	93.4	94.5	92.3	90.0	88.5	88.7	88.0	86.2	86.2	86.0
Precipitation / Rainfall (mm)	0	8	20	52	134	163	179	211	247	210	77	11

Figure 16-2 Average monthly temperature and rainfall in Siem Reap

There is a difference of 247 mm of precipitation between the driest and wettest months. Throughout the year, temperatures vary by 5.7 °C.

16.3. Climate Change Threat profile Siem Reap Province

The Siem Reap Province Climate Change threat profile is given below:

Table 16-2 Projected changes to average rainfall & maximum temperatures by 2050:

	Baseline	With C.C.	Change
Average annual rainfall:	1280 mm	1369 mm	+ 7.0%
Total rainfall in wet season:	1057 mm	1147 mm	+ 8.5%
Total rainfall in dry season (Nov - Apr):	223 mm	222 mm	- 0.5%
Average daily maximum temperature (Annual)	31.7 °C	34.0 °C	+2.3 °C
Average maximum temperature in wet season:	30.9 °C	33.6 °C	+2.7 °C
Average maximum temperature in dry season:	32.4 °C	34.5 °C	+1.9 °C

16.3.1. Projected changes to average rainfall & maximum temperatures by 2050

16.3.2. Wet season rainfall

By 2050, total rainfall in Siem Reap in the wet season would increase by about 8.5%.

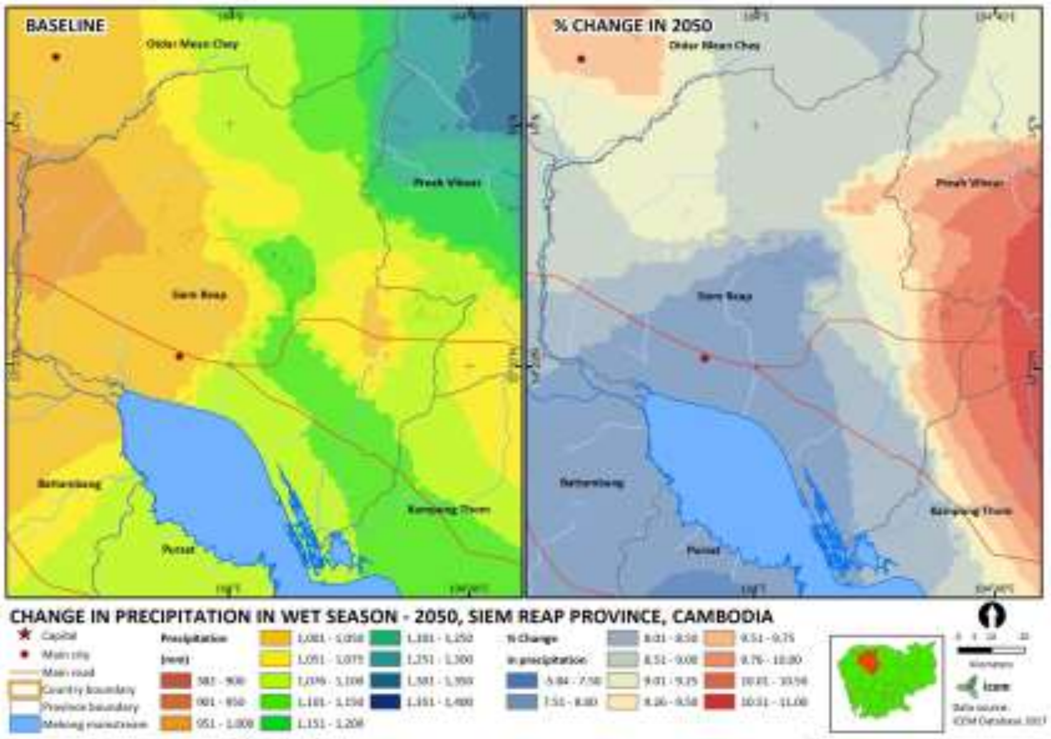


Figure 16-3   Siem Reap Wet Season Rainfall

16.3.3. Dry season rainfall

By 2050, total rainfall in Siem Reap in the dry season would increase by about 0.5%.

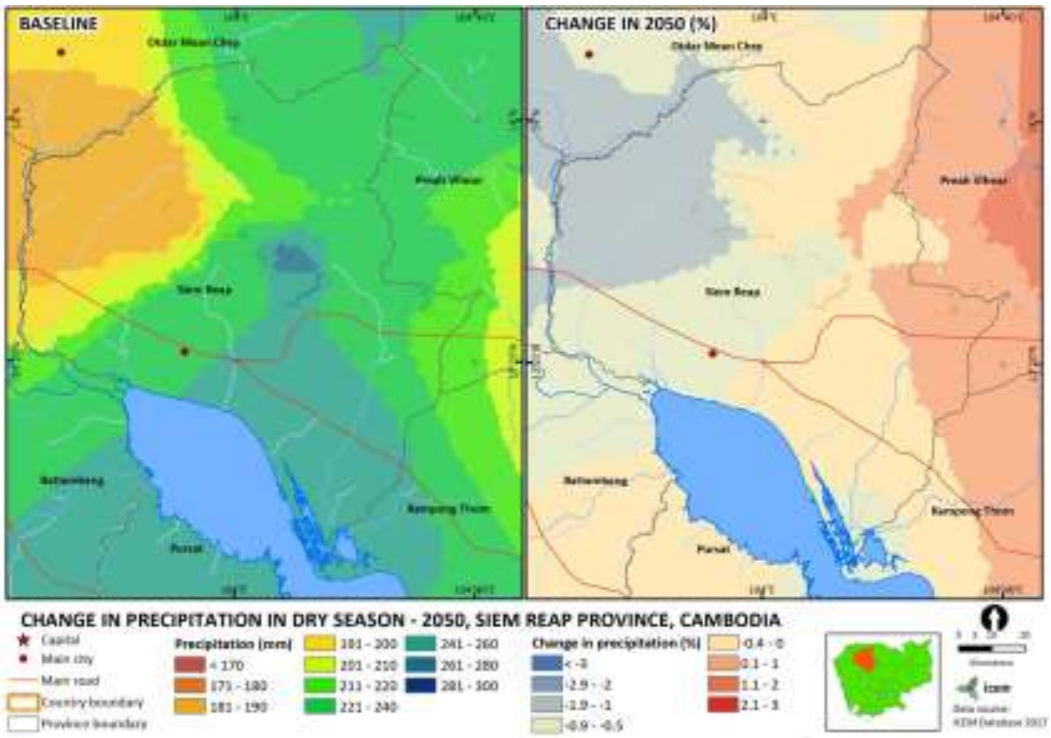


Figure 16-4   Siem Reap Dry Season Rainfall

16.3.4. Wet season temperature

By 2050, the average daily maximum temperature in Siem Reap in the wet season would increase by about 2.7 ^{0}C.

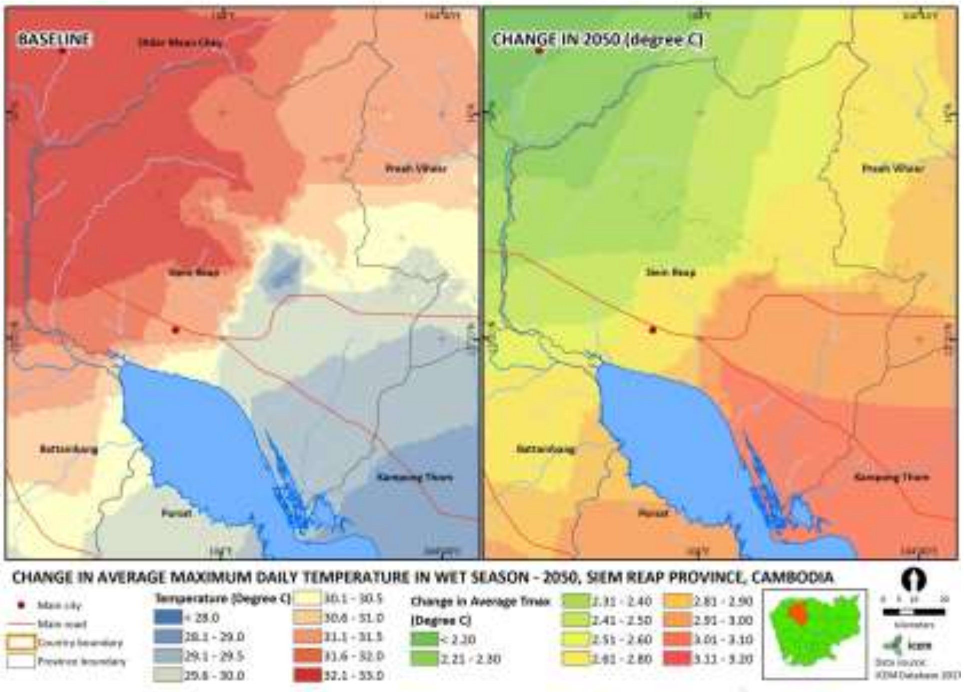


Figure 16-5 Siem Reap Wet Season Temperature

16.3.5. Dry season temperature

By 2050, the average daily max temperature in Siem Reap in the dry season would increase by between 1.8-2.2^{0}C.

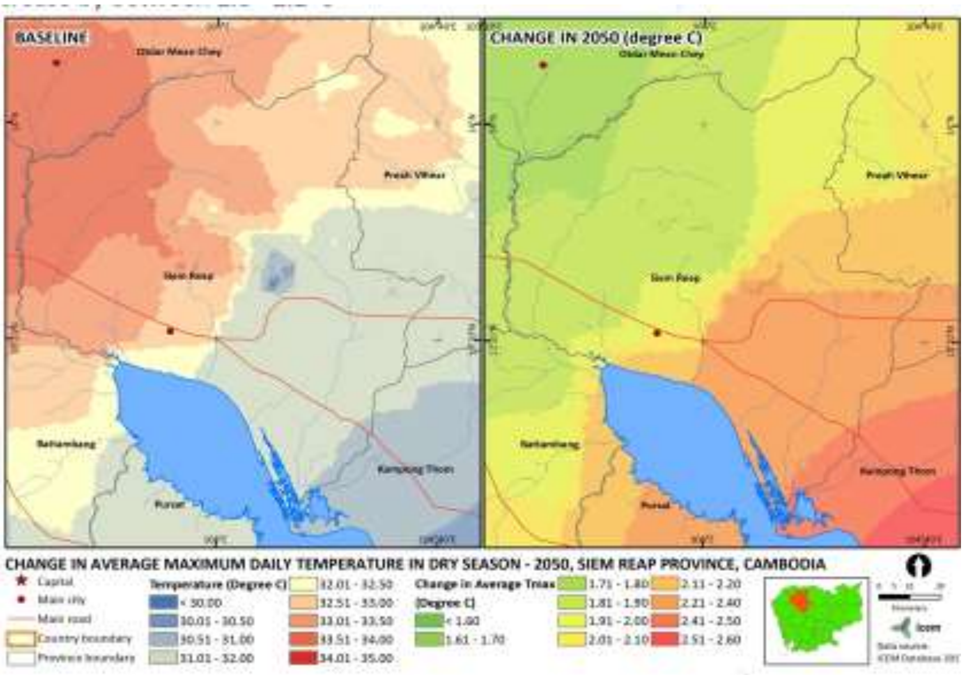


Figure 16-6 Siem Reap Dry Season Temperature

16.3.1. Siem Reap Floods

In 2011, Cambodia suffered a big flood. According to Red Cross there were 12 districts of Siem Reap and 66 communes affected by flooding. Furthermore 17,787 families and their houses were affected, 13 houses were damaged and 5,338 people were evacuated to high ground and safe places such as schools, pagodas and hospitals. Similar floods occurred again in 2013.

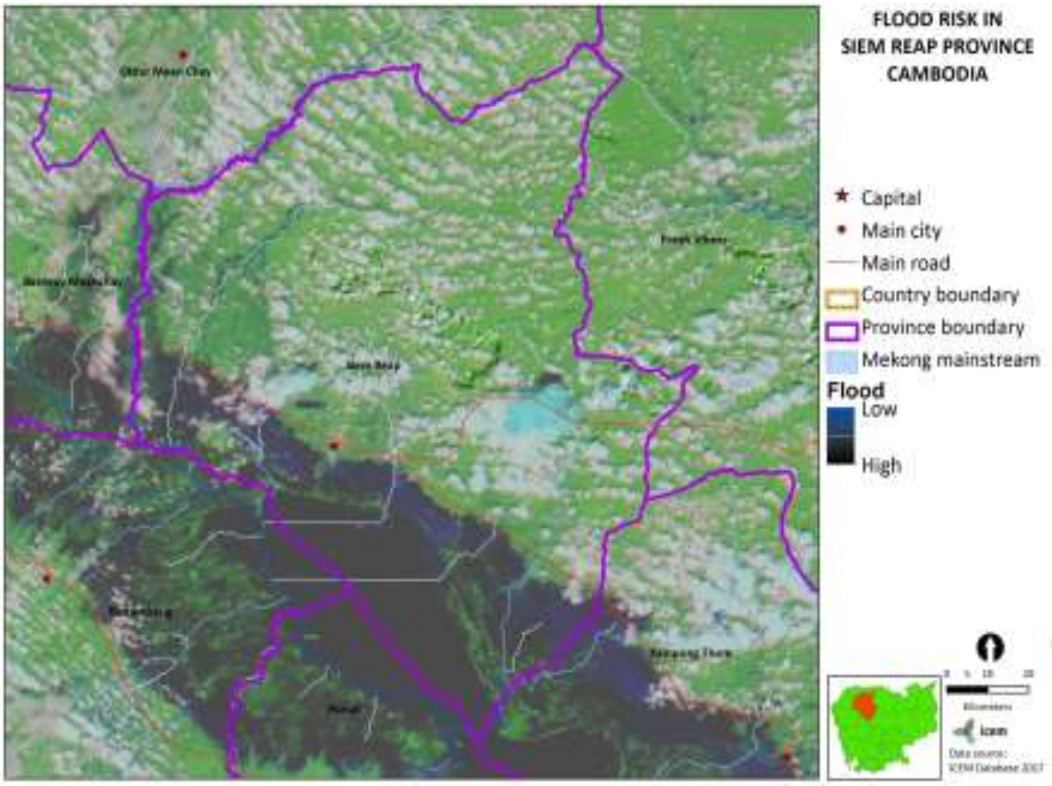


Figure 16-7 Flood Risk in Siem Reap Province

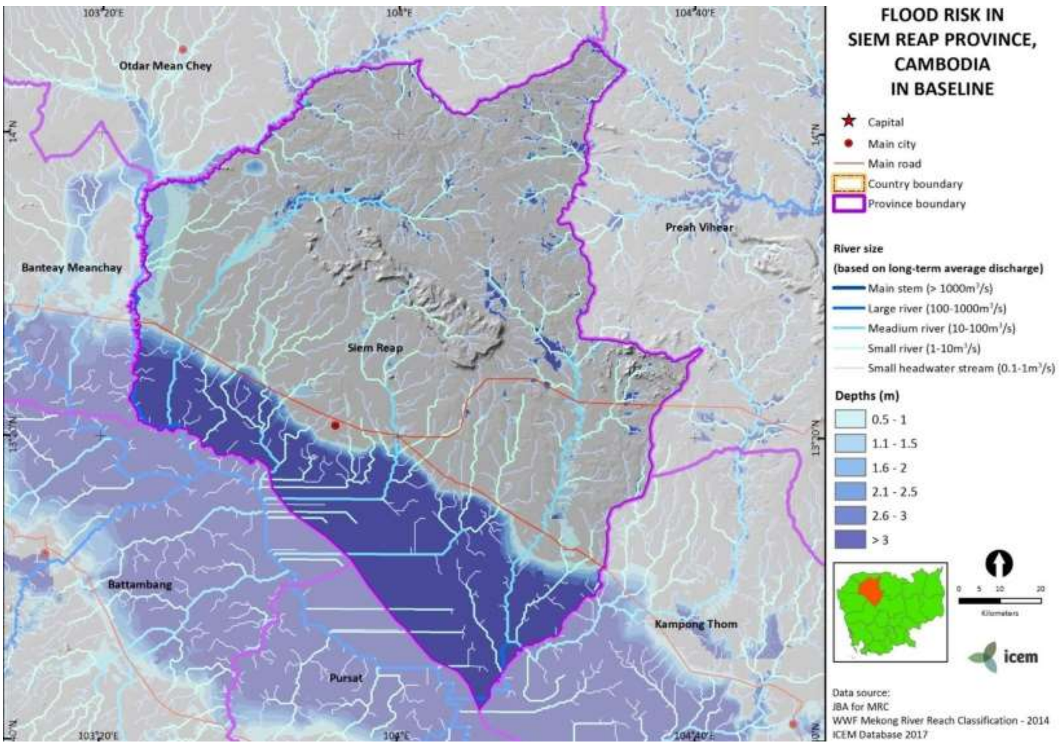


Figure 16-8 Flooding under Baseline Conditions

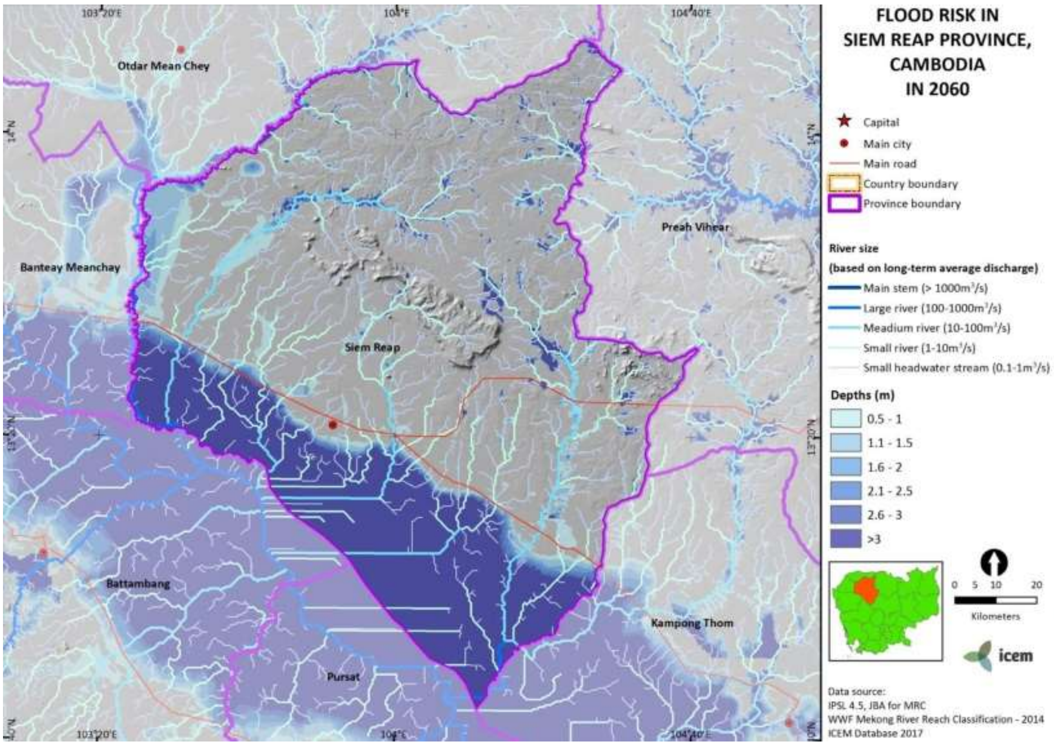


Figure 16-9 Flooding under Climate Change Scenario

Figure 16-10 Note sandbags on High Street and Siem Reap Provincial Hospital

16.3.1. Siem Reap Drought

Siem Reap is expected to be significantly hotter and wetter in the wet season, hotter in the dry season; the rainfall does not change significantly and the dry season is projected to be slightly longer.

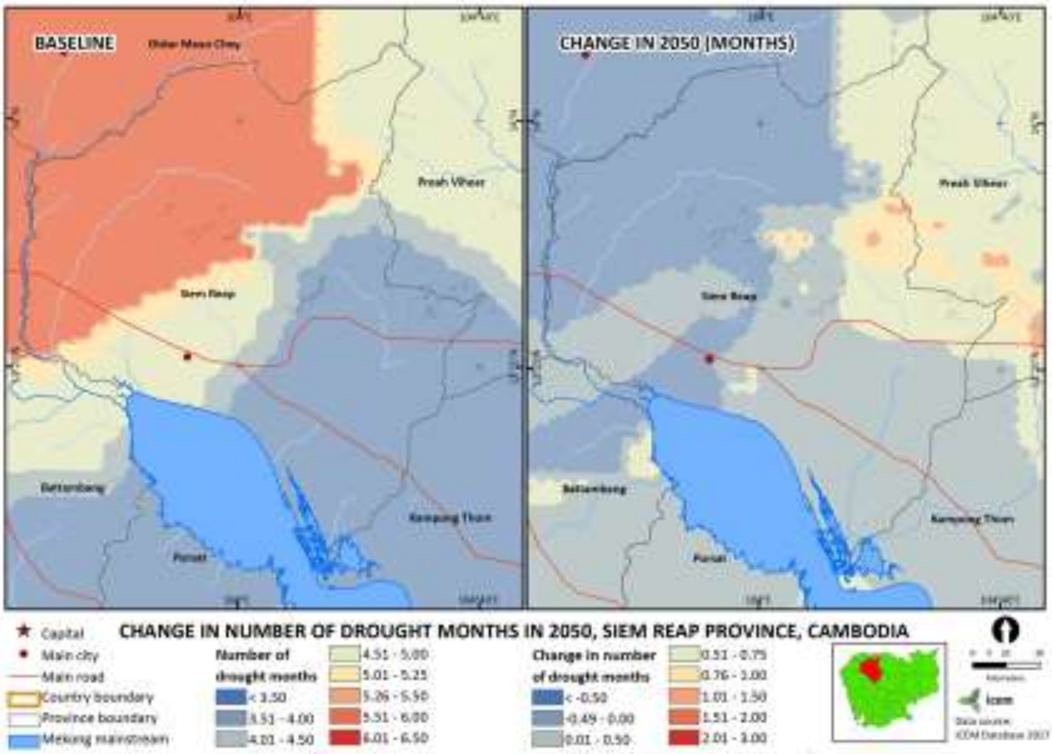


Figure 16-11 Siem Reap Drought Months

16.4. FRMI Climate Change Risks

205. The flood risk map for Siem Reap Province is shown below.

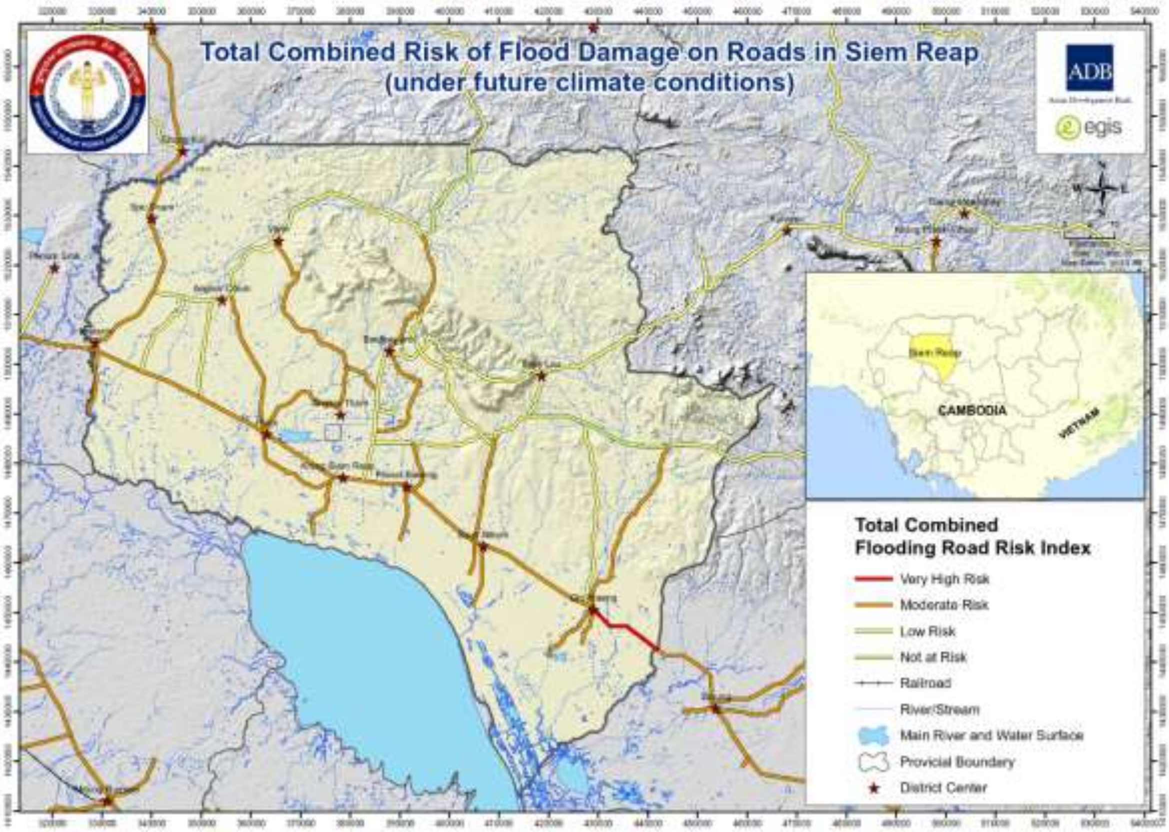


Figure 16-12 FRMI Flood Risk Map Siem Reap

206. The area in the city and to the north are classified as being at **Moderate Risk** of flooding and the areas to the south of the city are classified as being at **Very High Risk** of flooding due to the influence of Tonle Sap Lake.

16.5. Rainfall Intensity-Duration-Frequency (IDF) Curves for Siem Reap Province

Table 16-3 Siem Reap IDF

Duration t		**Intensity-Duration-Frequency (mm/hrs)** Siem Reap								
		Return Period, T								
		2	**3**	**4**	**5**	**10**	**20**	**25**	**50**	**100**
5	min	177	209	230	245	291	334	348	355	394
10	min	144	171	188	200	237	273	284	294	326
15	min	122	145	159	170	201	232	241	252	279
30	min	85.3	101	111	118	140	162	168	178	198
1	h	54.5	64.5	70.9	75.7	90	103	107	115	128
2	h	32.7	38.7	42.5	45.4	53.8	61.8	64.4	70.1	77.7
4	h	18.8	22.3	24.5	26.2	31.0	35.6	37.1	40.8	45.2
8	h	10.6	12.6	13.8	14.8	17.5	20.1	20.9	23.2	25.7
12	h	7.6	8.9	9.8	10.5	12.4	14.3	14.9	16.6	18.4
18	h	5.4	6.3	7.0	7.4	8.8	10.1	10.6	11.8	13.1
24	h	4.2	5.0	5.5	5.8	6.9	7.9	8.3	9.3	10.3

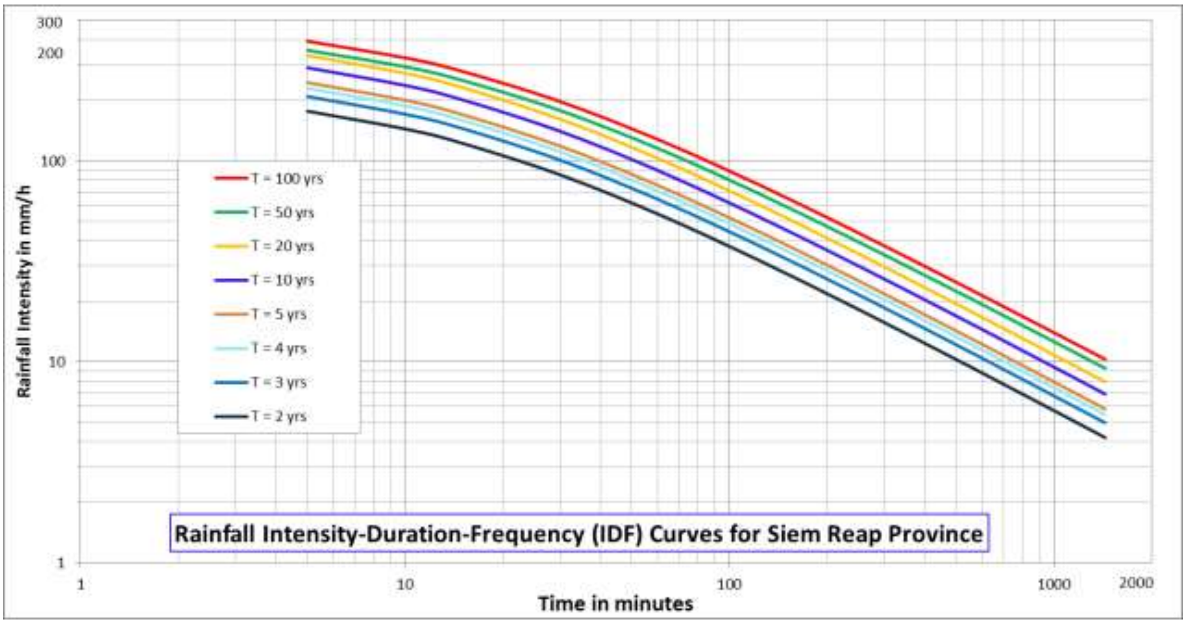


Figure 16-13 Siem Reap IDF

17. STUENG SAEN, KAMPONG THOM PROVINCE

17.1. Location

Kampong Thom is Cambodia's second largest province by area and borders the provinces of Siem Reap to the northwest, Preah Vihear to the north, Stung Treng to the northeast, Kratie to the east, Kampong Cham to the south and the lake of Tonle Sap to the west.

The provincial capital is Stung Saen, a town of approximately 30,000 people on the banks of the Stung Sen River. The Stung Sen River flows through the town and although the benchmark is 11.40 metres water levels regularly reach to 12.16 metres and cause flooding.

Much of Kampong Thom is located on the floodplain of the Tonlé Sap lake. As one of the nine provinces bordering Tonle Sap Lake, Kampong Thom is part of the Tonlé Sap Biosphere Reserve. Two of the three core areas in Tonlé Sap Biosphere Reserve are located in Kampong Thom. These are Boeng Chhmar (14,560 hectares), and Stung Saen (6,355 hectares).

Figure 17-1 Location Kampong Thom

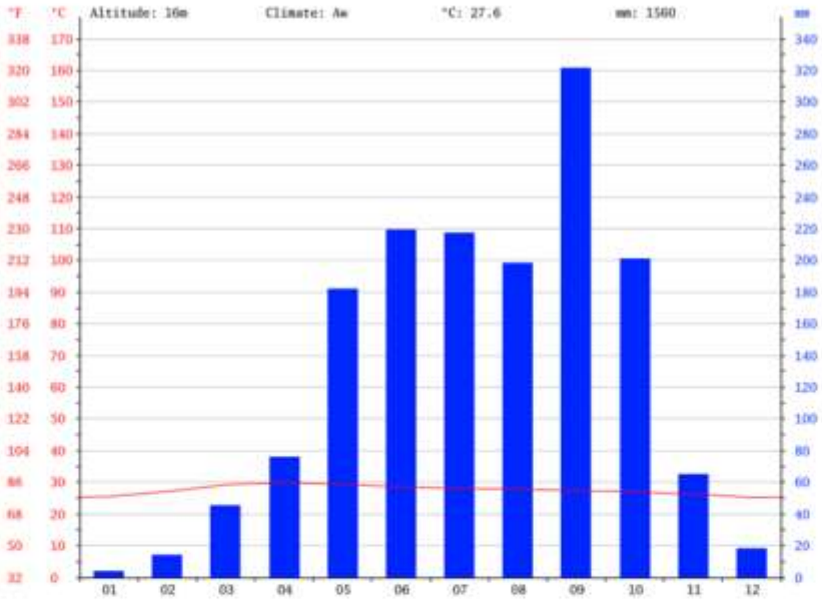
There are a number of significant pre-Angkor sites in the area, including Prasat Sambor Prei Kuk which is a candidate for UNESCO classification. This is one of more than 200 ancient temples in the province.

17.2. Rainfall

Kampong Thom was the most badly affected province in the floods of 2011 in Cambodia. Half of the local population was disrupted by the flood. The rainy season is May to November. October is the wettest month and January is the driest month.

Rainfall data for Kampong Thom is given below.

Table 17-1 Climatograph Kampong Thom



	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	25.5	27.1	29.2	30	29.3	28.6	28	27.9	27.4	27	26.2	25.3
Min. Temperature (°C)	19.8	21.6	24.1	25.1	24.9	24.6	24.3	24.3	24	23.4	21.9	20.1
Max. Temperature (°C)	31.2	32.7	34.4	35	33.7	32.6	31.7	31.5	30.9	30.6	30.6	30.5
Avg. Temperature (°F)	77.9	80.8	84.6	86.0	84.7	83.5	82.4	82.2	81.3	80.6	79.2	77.5
Min. Temperature (°F)	67.6	70.9	75.4	77.2	76.8	76.3	75.7	75.7	75.2	74.1	71.4	68.2
Max. Temperature (°F)	88.2	90.9	93.9	95.0	92.7	90.7	89.1	88.7	87.6	87.1	87.1	86.9
Precipitation / Rainfall (mm)	4	14	45	76	182	219	217	198	321	201	65	18

Figure 17-2 Monthly Climate Kampong Thom

The average annual temperature in Kampong Thom is 27.6°C. The rainfall averages 1560 mm per year.

17.3. Climate Change Threat profile Kampong Thom Province

The Kampong Thom Province Climate Change threat profile is given below:

Table 17-2 Projected changes to average rainfall & maximum temperatures by 2050:

	Baseline	CC Scenario	Change
Average annual rainfall:	1294 mm	1411 mm	9.1 %
Total rainfall in wet season:	1086 mm	1201 mm	10.7 %
Total rainfall in dry season (Nov - Apr):	208 mm	210 mm	0.9 %
Average annual number of drought months	4.2 months	4.8 months	+ 0.6 months
Average daily maximum temperature (Annual)	31.0 °C	33.0 °C	+ 2.0 °C
Average maximum temperature in wet season:	29.6 °C	32.5 °C	+ 2.9 °C
Average maximum temperature in dry season:	31.2 °C	33.6 °C	+ 2.3 °C

17.3.1. Projected changes to average rainfall & maximum temperatures by 2050

17.3.2. Wet season rainfall

By 2050, total rainfall in Kampong Thom in the wet season would increase by about 10.7%.

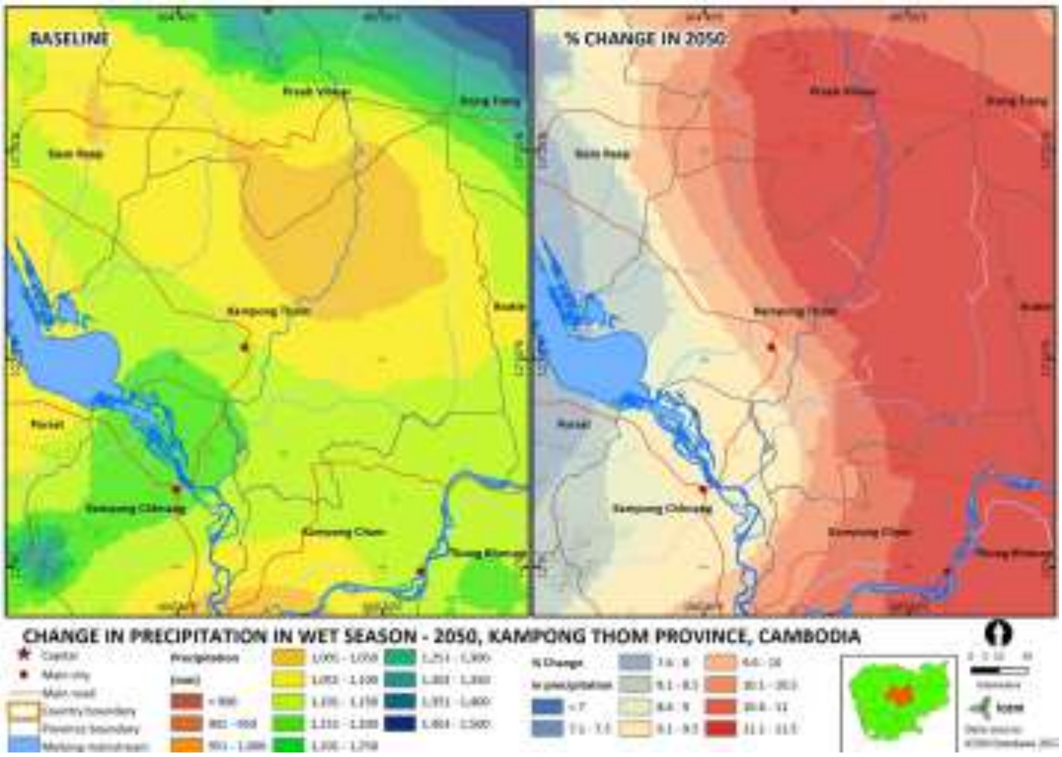


Figure 17-3 Kampong Thom Wet Season Rainfall

17.3.3. Dry season rainfall

By 2050, total rainfall in Kampong Thom in the dry season would increase by about 0.9%.

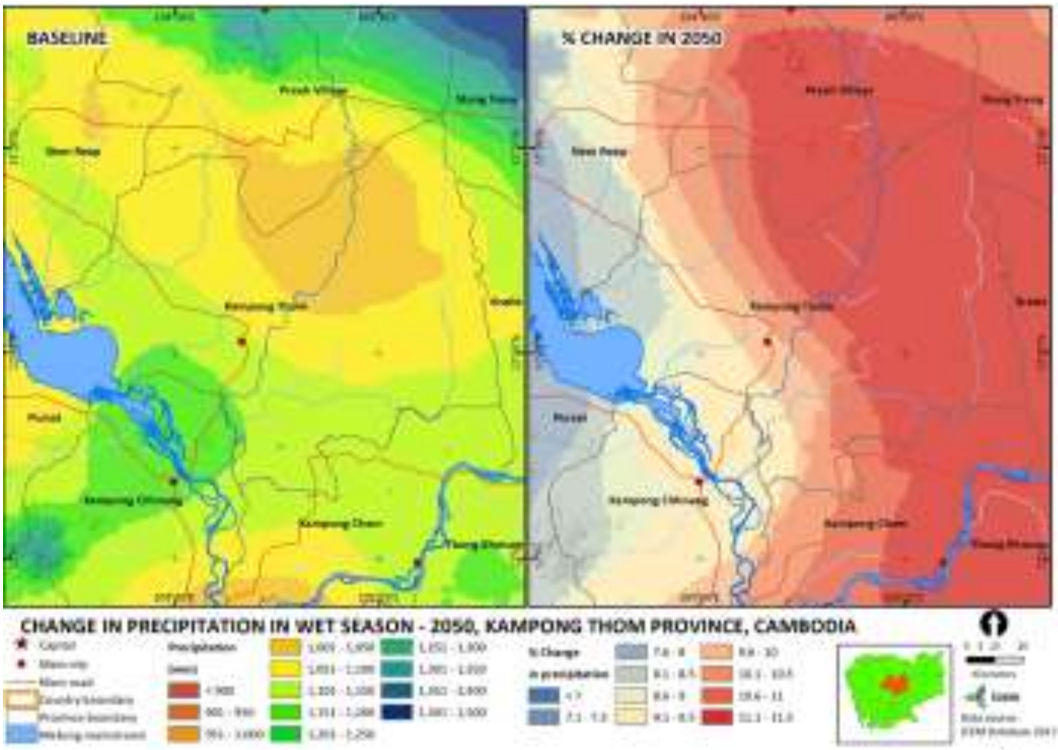


Figure 17-4 Kampong Thom Dry Season Rainfall

17.3.4. Wet season temperature

By 2050, the average daily maximum temperature in Kampong Thom in the wet season would increase by about 2.9 ^{0}C.

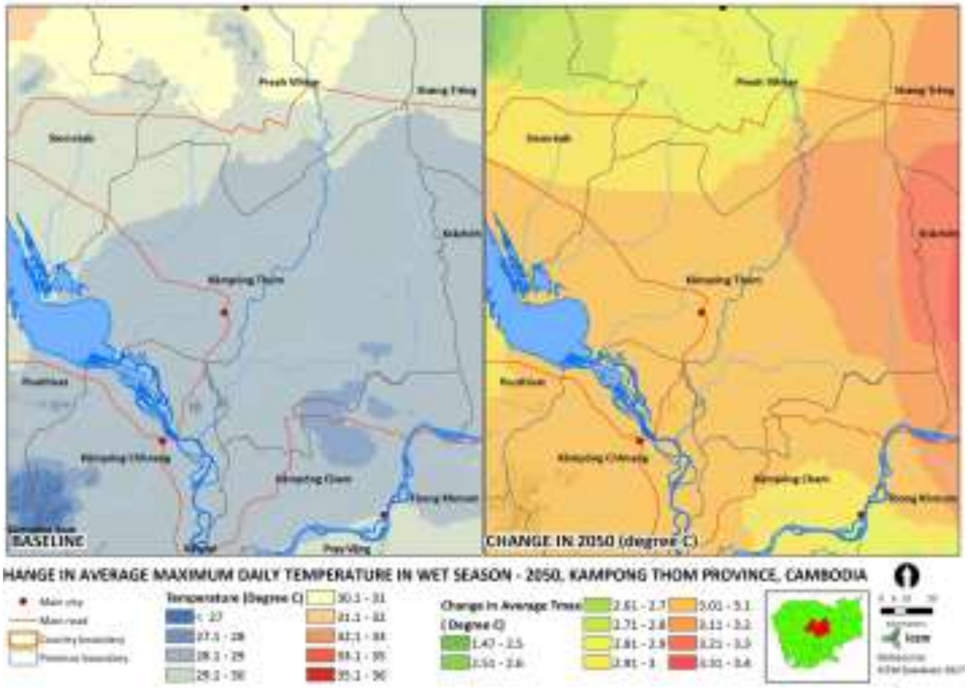


Figure 17-5 Kampong Thom Wet Season Temperature

17.3.5. Dry season temperature

By 2050, the average daily max temperature in Kampong Thom in the dry season would increase by about 2.3 ^{0}C.

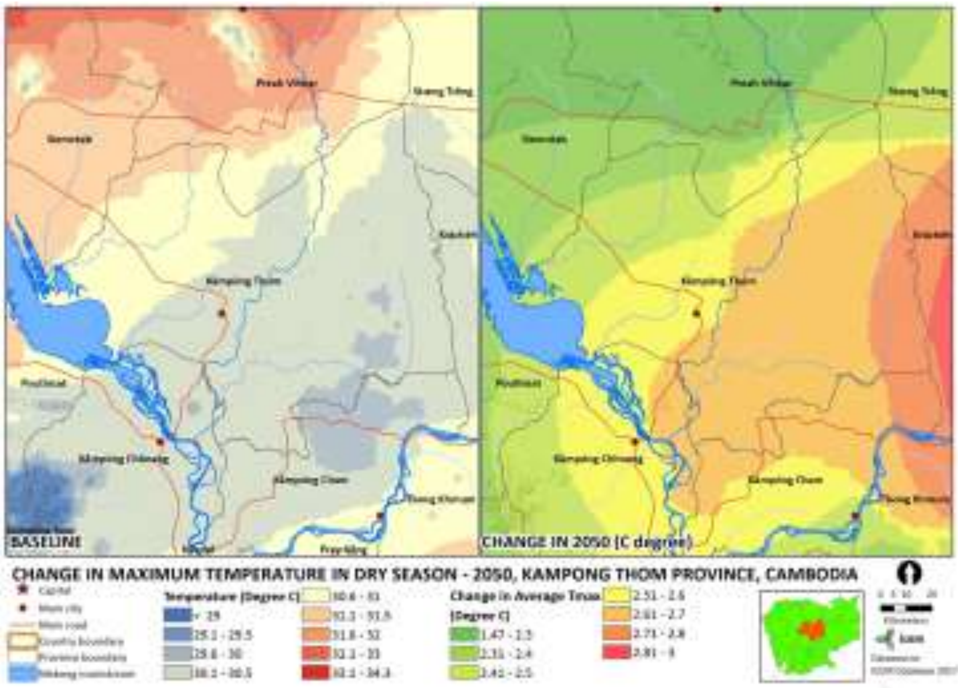


Figure 17-6 Kampong Thom Dry Season Temperature

17.3.1. Kampong Thom Floods

Kampong Thom is one of the most vulnerable provinces to the natural disaster especially flood in Cambodia. In 2011, 40 percent of the total population among 8 districts of Kampong Thom was affected by a serious flood. It was reported that 54,414 families of 7 districts and 1 municipality in Kampong Thom were affected by flood and 64 people dead (17 women and 21 children). Also 64,872 ha of wet season rice and some infrastructures were damaged

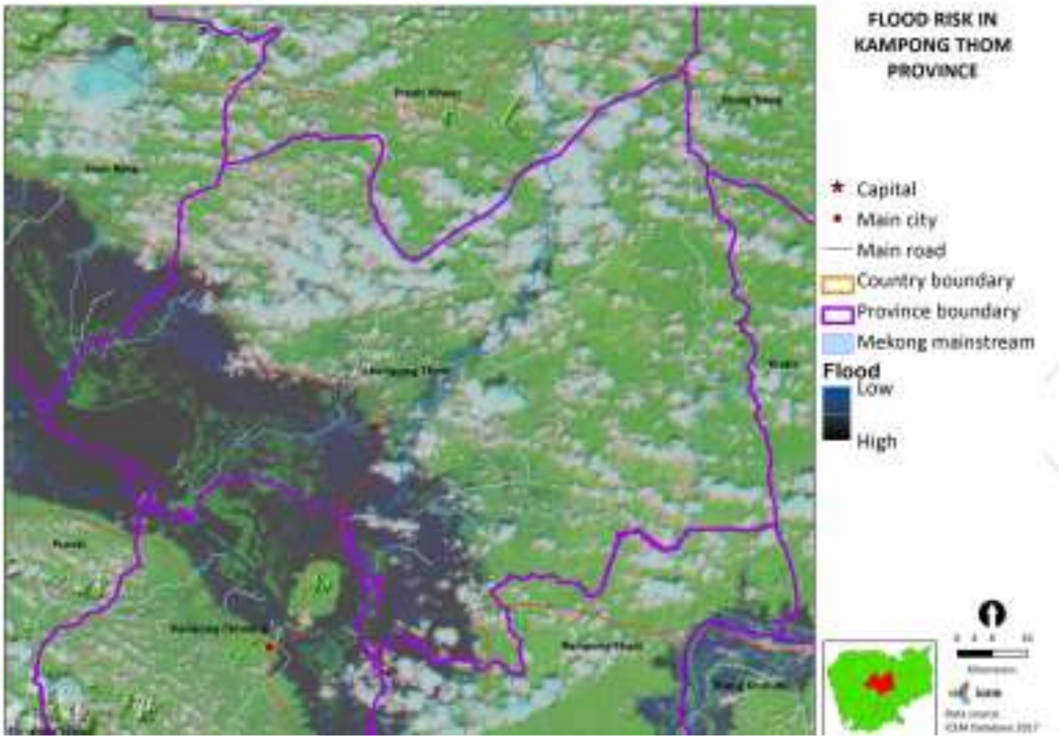


Figure 17-7 Extent of 2011 Flood in Kampong Thom

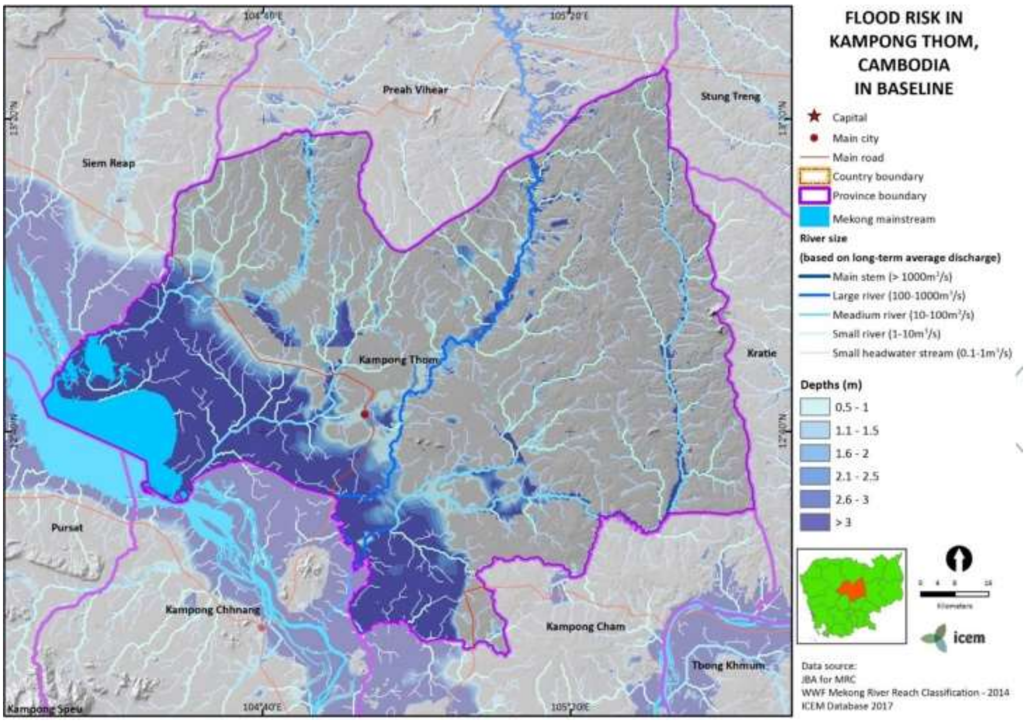


Figure 17-8 Flooding Baseline Conditions 35% of Province

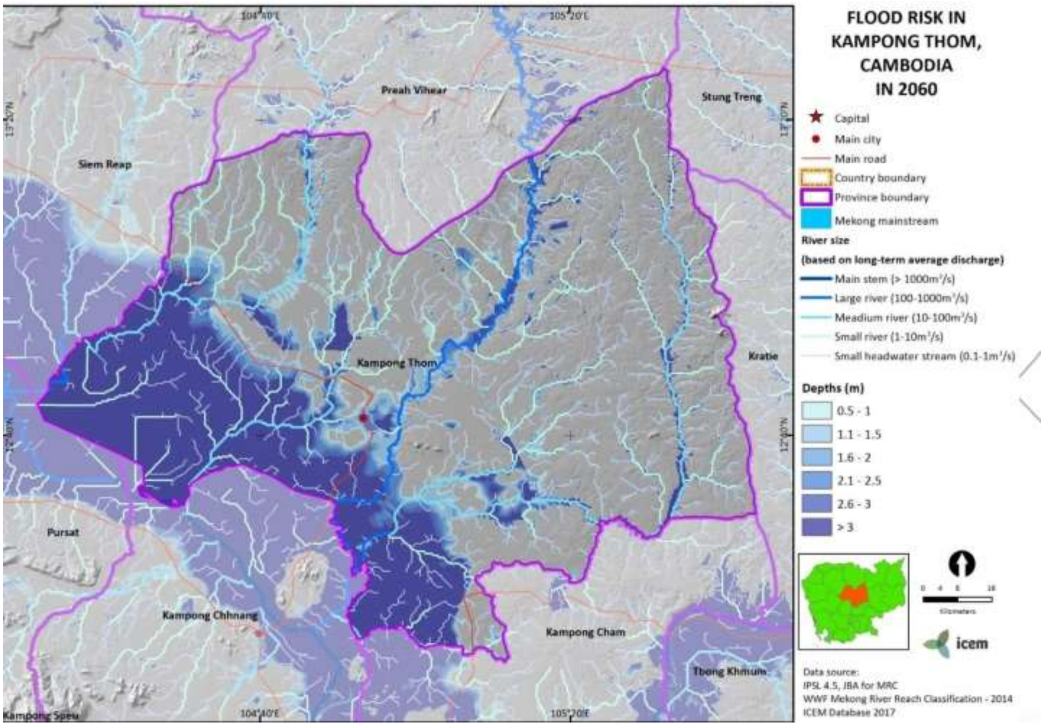


Figure 17-9 Flooding with Climate Change Conditions

17.3.1. Kampong Thom Drought

Kampong Thom is expected to be significantly hotter and wetter in the wet season; significantly hotter and slightly wetter in the dry season; and have a slightly greater number of drought months.

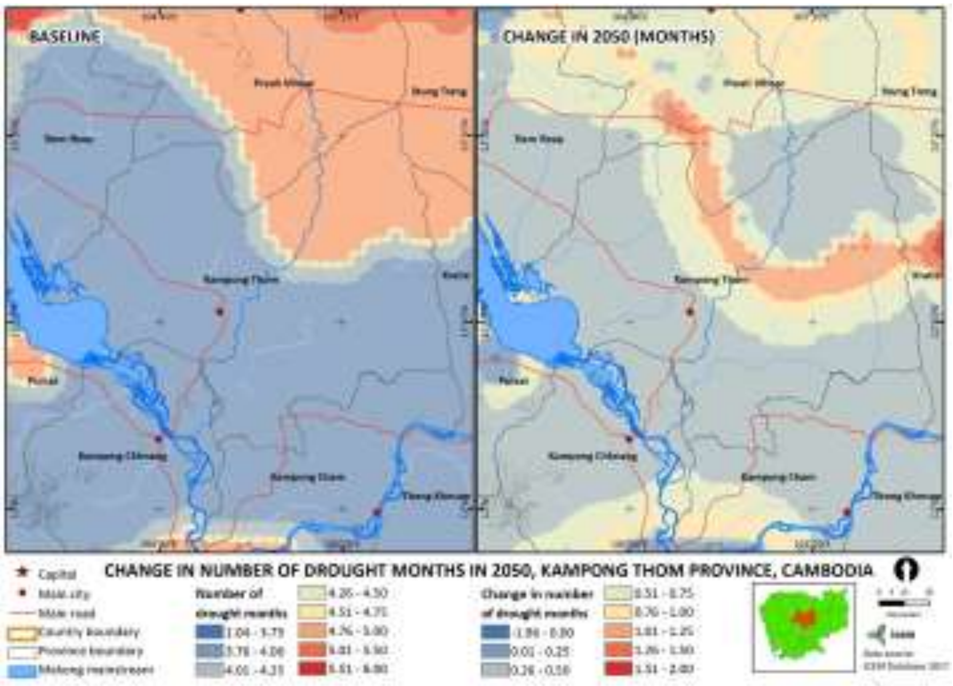


Figure 17-10 Change in Number of Drought Months

17.4. FRMI Climate Change Risks

207. The flood risk map for Kampong Thom Province is shown below.

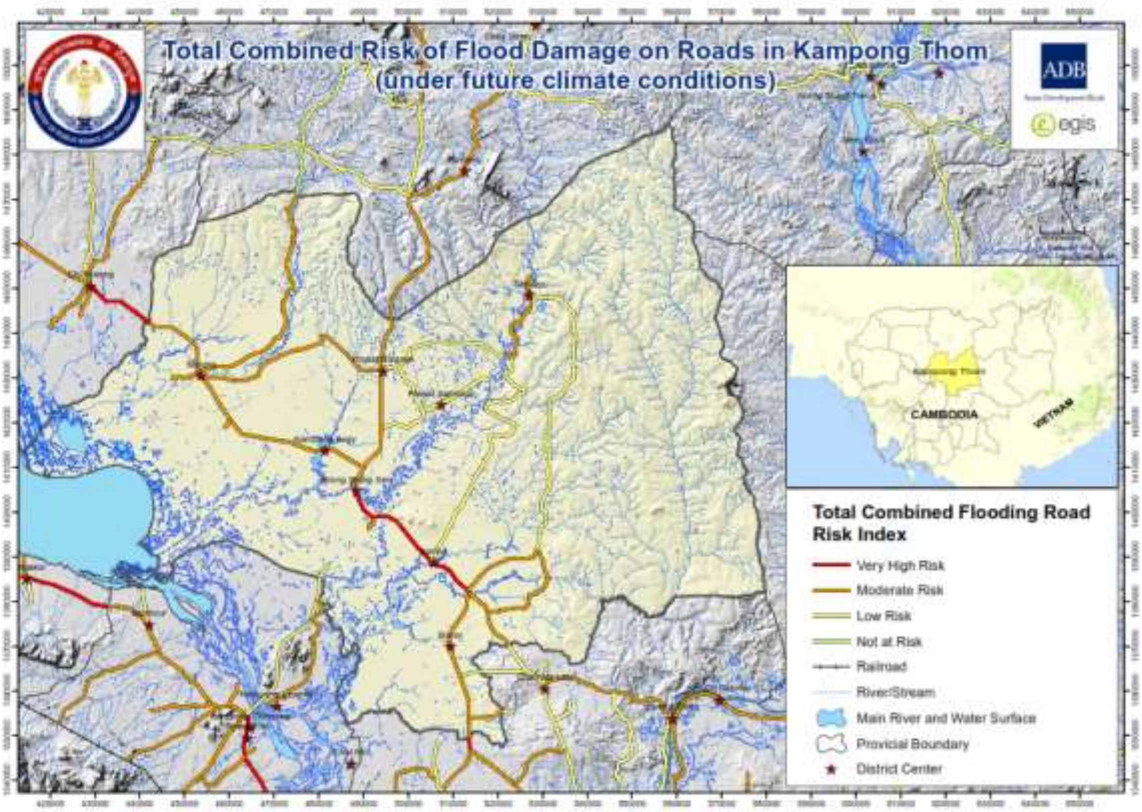


Figure 17-11 FRMI Flood Risk Map Stung Saen, Kampong Thom Province

208. The sites are in locations that are classified as being at **Moderate to Very High Risk** of flooding.

17.5. Rainfall Intensity-Duration-Frequency (IDF) Curves for Kampong Thom Province

Table 17-3 Kamponh Thom IDF

Duration t		**Intensity-Duration-Frequency (mm/hrs)** Kampong Thom								
		Return Period, T								
		2	**3**	**4**	**5**	**10**	**20**	**25**	**50**	**100**
5	min	161	178	188	196	219	241	248	245	264
10	min	132	145	154	160	179	197	202	202	219
15	min	112	123	130	136	152	167	172	173	187
30	min	78.0	86	91	95	106	116	120	123	133
1	h	49.8	54.8	58.1	60.5	68	74	76	80	86
2	h	29.8	32.9	34.8	36.2	40.5	44.5	45.8	48.3	52.1
4	h	17.2	19.0	20.1	20.9	23.3	25.7	26.4	28.1	30.4
8	h	9.7	10.7	11.3	11.8	13.2	14.5	14.9	16.0	17.3
12	h	6.9	7.6	8.1	8.4	9.4	10.3	10.6	11.4	12.3
18	h	4.9	5.4	5.7	5.9	6.6	7.3	7.5	8.1	8.8
24	h	3.8	4.2	4.5	4.7	5.2	5.7	5.9	6.4	6.9

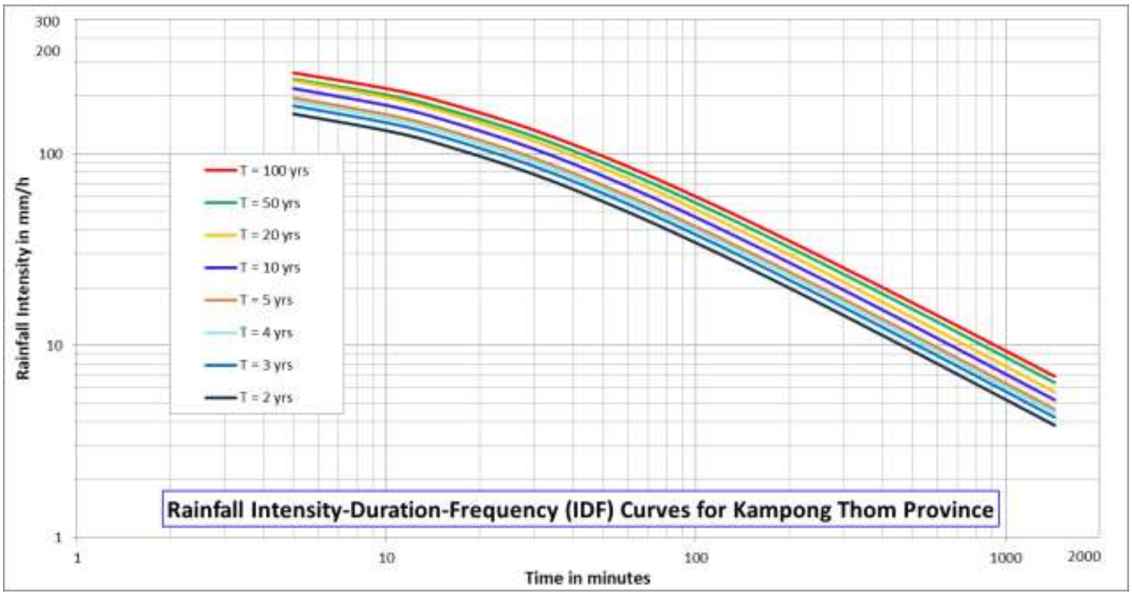


Figure 17-12 Kampong Thom IDF

18. APPROACH TO CLIMATE CHANGE IN DETAILED DESIGN

18.1. Rainfall

209. Knowing what rainfall intensity and duration figures apply is absolutely fundamental in any climate resilient design. This applies not only to drainage but also to the elevation of a site above any likely flood levels. (This is known as freeboard.)

18.2. Projections of Annual Precipitation

210. The overall conclusion is that annual precipitation around Tonle Sap will rise slowly, if at all.

18.3. Monthly Increase during Flood Period

211. The main change in rainfall will occur in the three wettest months of the year, August, September and October. In low lying areas flooding is generally caused by the rainfall in the wettest months of the year and lasts for several weeks. In such a case, changes in monthly rainfall are of more importance than rain falling over a shorter time period. Projections suggest that the will be little, if any, increase by 2030 but could increase by over 20% by 2070.

18.4. Storm Projections

212. A paper by O'Gorman in Nature Geoscience Letters[21] related increases in precipitation to increases in temperature and shows that for extreme storm events (0.01% probability of occurrence or less) precipitation increases by 10% for each degree of increase in temperature.

213. As temperature increases are hoped not to exceed 2ºC by the end of this century then an addition of 20% on intensity of short duration extreme storms would account for climate change.

18.5. Overview of Precipitation Changes

214. The following table summarises the expected change to precipitation for different periods. They are based on the average of 4 models for RCP6.0 projection.

Table 18-1 Change in Rainfall % (RCP 6.0)

Year	Annual	Rainy season	Month	5-day	1-day
2030	-1	-3	-1	12	7
2050	0	3	12	19	10
2070	4	7	8	35	32

215. The main conclusions from the above as they relate to precipitation are:

- Annual rainfall may remain unchanged but rainfall will increase more in the wettest months by being of stronger duration. This will lead to longer dry periods. There may be "mini-droughts" during the wet season.
- Precipitation will increase most in the south-west of Cambodia and decrease in the north-east of Cambodia.
- Both the maximum 5-day and 1-day storms are expected to increase. The projected increases are 10% for 2030, 20% for 2050 and 30% or more for 2070.

[21] *'Sensitivity of tropical precipitation extremes to climate change' in Nature Geoscience Letters, September 2012.*

- The relative increase in rainfall is heavier for short durations.
- An increase of 20% on existing IDF curves will allow for a global temperature increase of 2°C. This factor is conservative and is recommended as a design factor.
- A figure of 30% may be applied for extreme climate change cases.

18.6. Adaptation Measures

216. Adaptation to climate change in infrastructure design may require intervention at several stages. Some modifications can be introduced at preliminary design, other items will be required at detailed design phase.

Table 18-2 Climate Change Adaptation Measures

Civil Works • Increased height of access road above flood levels • Raise embankment on Lagoons boundaries • Modification of side slope ratios to avoid soil loss in heavy rain
Hydrological Studies • Coordination of data collection/recording systems e.g. rainfall, stream gauges • Adjustment of design criteria to account for increased flows • Allowances for effects of future dam and irrigation schemes.
Drainage Design • Additional waterway opening at bridge sites • Additional cross-culvert capacity • Debris defectors and energy dissipaters • Install Debris Deflectors • Sub-drainage systems. • Turf surfaces on side slopes.
Erosion Controls • Side ditch linings in areas of high flow velocity • Retaining walls and gabions to stabilize slopes • Bioengineering of embankments
Operations and Maintenance • Regular inspection and repair of drainage systems • Regular cleaning of culverts and side ditches • Regular cleaning of box and pipe culvert systems • Cleaning of culverts before known storms or typhoons • Quick restoration of items following major flood events.

18.7. Specific Recommendations from MPWT

217. MPWT have produced a series of Design Guide Recommendations that incorporate climate resilience. For full details reference should be made to the MPWT Guidance Note (see Section 2.9 Reference Materials.)

18.8. Field Work and Ground Truthing

218. Engineers must visit the site areas and enquire for local characteristics of floods and update flood information from the relevant authorities before deciding on a design elevation. Historical extreme flood elevation maps and 100 Year flood depth maps should be used for general guidance only.

18.9. Elevation

219. For access roads the crest level should be a minimum height of the water level of floods with a recurrence interval of 1 in 10 years plus 0.25 meters.

18.10. Flood Calculations

220. The commonly used Rational Method can only be applied to catchment areas less than $10km^2$. For larger areas the Generalised Tropical Flood Model (GTFM) developed by Fiddes and Watkins (1984) should be used.

18.11. Embankments

221. A layer of soil shall be constructed over the completed and trimmed side slopes of embankments. A complete dense cover of growing grass shall be established on the soil covering the side slopes. Where the side of an embankment is subject to wave action, a hedge of shrubs shall be established growing on a line 1.2 m in elevation below the top edge of the roadway.

18.12. Drainage Design

222. IDF curves must be used very cautiously in design. Error factors of 2 to 1 are common. However overestimating the anticipated rainfall will give a higher safety factor in the design of the drains.

18.13. Maintenance

223. The importance of maintenance cannot be over emphasized. No matter how good the design a lack of maintenance will render it ineffective. Bar screens should be installed on upstream inlets to pipes to catch floating debris. Vertical screens are easier to clean by manual labor.

224. Local communities can be hired for drain cleaning and grass cutting. This only needs unskilled labor and providing of some simple tools. The community sense of ownership can improve the efficiency of maintenance.

19. CAMBODIA BUILDING CODE REVISIONS

19.1. Cambodia Building Code

225. The TOR requires us to make suggestions on sanitation and latrines leading to revisions to the Building Code. Despite our best endeavours we have been unable to obtain a copy of the Cambodian Building Code. We are informed by architects and civil engineers that we have contacted that they follow other countries codes such as the ACI from USA which is the American Concrete Institute.

226. There is no Standard Cambodia National Building Code yet although Ministry of Land Management, Urban Planning and Construction issue documents related to "*the sub-degree on the urbanization of the Capital Municipality and Urban Areas and draft National Urban Development Strategy Framework as well as the Map of Height Control Zone".*

227. We are informed that the Building Code is under revision by the Ministry of Land Management, Urban Planning and Construction. We will continue to research the status of this document.

228. This raises the question as to how revisions can be made to a document that is not currently implemented and enforced.

19.2. Proposed Draft Amendments for Sanitation

229. A recent relevant document is "Strengthening the Disaster Management Systems in Cambodia through Risk Assessment, Early Warning System, and Developing Building Codes" under Development of Construction Guidelines and Codes for Housing and Buildings through the National Committee for Disaster Management (NCDM) to implement Ketsana Emergency Reconstruction and Rehabilitation Project (KERRP). This document contains a section on sanitation.

230. There is a huge demand for flood resistant, appropriate, socially and culturally accepted technological options for safe disposal of human excreta in the flood prone areas. However, there are limited technological options for sanitation for flood prone areas for sanitation and desludging to reduce health risk. The minimal requirements of sanitation facilities are :

- Technologies and structure and their application should be such that it does not contaminate the environment; and the use of sanitation service prevents disease transmission;
- Sanitation services should be affordable for all, socially acceptable and do not compromise the dignity of the uses, women, in particular;
- Technologies and structure are durable and their repair and maintenance are within the reach of the households; one latrine for each household; to achieve this target appropriate technology should be developed.

231. A comparison of disaster risk reduction compliant options is given in table 19-1

Table 19-1 Sanitation Options

Technology Option	Single Ventilated Pit Latrine	Raised Pit Latrine with cement base	Fossa Alterna	Single Pit for Pour Flush Latrine	Twin Pits for Pour Flush Latrine	Water Sealed Pit Latrine
Flood resistance	No, if there is flood	Yes	No, if not raised and there is flood	Yes, if floor pan level is raised	Yes, if floor pan level is raised	Yes, if floor pan level is raised
Cyclone resistance	Depending on materials used for cabin	Yes, but also depending on materials used for cabin	Depending on materials used for cabin	Yes, if in-built	Yes, if in-built	Yes, if in-built
Sustainability	Short-term	Long-term	Long-term	Long-term	Long-term	Long-term
Economic aspects	Low	Medium	Medium	Relatively high	Relatively high	Relatively high
Operation Maintenance	Easy	Easy	Easy	Medium	Medium	Medium
Dislodging	Pit can be filled up with faeces and need dislodging	Pit can be filled up with faeces and need dislodging	Pit can be filled up with faeces and need dislodging	Pits can be filled up with faeces and need dislodging	Pits can be filled up with faeces and need dislodging	Pits can be filled up with faeces and need dislodging
Skills required	No specific skills required	Masonry skills required	No specific skills required	No specific skills required	Skills required for piping and switch chamber	No specific skills required
Remarks	Recommended for areas with no floods	Recommended for areas with high floods	Highly recommended for areas with no floods	highly accepted by dwellers	Highly accepted by dwellers	highly accepted by dwellers

A recent study has given advice on climate proofing buildings against extreme weather events.[22] Details on buildings and sanitation are given in Annex 2.

[22] *"Strengthening the Disaster Management Systems in Cambodia through Risk Assessment, Early Warning System, and Developing Building Codes" under Development of Construction Guidelines and Codes for Housing and Buildings through the National Committee for Disaster Management (NCDM) to implement Ketsana Emergency Reconstruction and Rehabilitation Project (KERRP).*

20. SHORT TERM RAINFALL

20.1. Phnom Penh Weather Station

The main weather station is in Phnom Penh attached to the international airport. Phnom Penh receives an average of 1407 mm of rainfall per year, but there is a distinct wet and dry season. On average there are 121 days per year with more than 0.1 mm of rainfall (precipitation). The driest weather is in January when an average of 7 mm of rainfall (precipitation) occurs. The wettest weather is in October when an average of 257 mm of rainfall (precipitation) occurs.

Table 20-1 Precipitation Table

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Precipitation mm	7	10	40	77	134	155	171	160	224	257	127	45	1407
Precipitation mm	7	10	40	77	134	155	171	160	224	257	127	45	1407
Number of Wet Days (probability of rain on a day)	1 (3%)	1 (4%)	3 (10%)	6 (20%)	14 (45%)	15 (50%)	16 (52%)	16 (52%)	19 (63%)	17 (55%)	9 (30%)	4 (13%)	121 (33%)

The relationship between rainfall intensity and duration is expressed in the form:

$$I = \frac{a}{(b+T)^n}$$

where

I = Rainfall intensity (mm/hr)

T = Duration (hr)

And : a, b and n are constants

The rainfall intensity equation can be rewritten to plot as a straight line:

Loge I = loge a – n loge (b+T)

Thus the optimum values of the constants a, b and n can be found by entering values of loge I and loge (b + T) into a linear regression equation program for a range of values of b, then selecting the equation that gives the closest fit to a straight line.

To define the coefficients a, b and n, one needs data obtained by recordings from rain gauges. This should ideally be 15 to 20 years duration and be for very short periods from 5 minutes to 24 hours.

The data from Pochentong are based on half hourly measurements. These can be used to derive the regression coefficients in the formula for short term rainfall intensity. The constants were determined for return periods of 2.33, 10 and 50 years as shown below:

Table 20-2 Pochentong Regression Coefficients

Return	Regression equation constants		
Period	a	b	n
2.33 years	48	0.18	0.80
10 years	79	0.23	0.86
50 years	108	0.25	0.85

These constants are then used to determine rainfall for other time durations and for other return intervals. These allow a full IDF curve to be drawn.

20.2. Rainfall Ratio Method

The Rainfall Ratio Method allows rainfall to be estimated from 24-hour rainfall of a known frequency (return period) by applying the relationship:

$$RR_t = \frac{t}{24}\left(\frac{b+24}{b+t}\right)^n$$

Where:

RRt = Rainfall ratio Rt:R24

Rt = Rainfall in a given duration 't' in hours

R24 = Rainfall in 24 hours

n, b are constants from the regression

t is time in hours

This gave the table below:

Table 20-3 Pochentong IDF and DDF

Duration t	Distribution of 24 h Rainfall Depth (mm)								
	Retun Period T , years								
	2	3	5	10	15	20	25	50	100
5 min	11.5	12.6	15.0	18.1	19.6	20.6	21.5	22.0	25.0
10 min	18.5	20.3	24.3	29.6	32.0	33.6	35.1	36.5	41.3
15 min	23.3	25.6	30.8	37.7	40.7	42.8	44.6	46.9	53.1
30 min	32.3	35.5	42.8	52.5	56.7	59.7	62.3	66.4	75.2
45 min	37.7	41.5	50.0	61.1	66.1	69.5	72.5	78.0	88.3
1.0 h	41.6	45.7	54.9	67.1	72.5	76.2	79.5	86.0	97.4
1.5 h	47.0	51.7	61.7	75.0	81.1	85.3	88.9	96.9	110
2.0 h	50.9	55.9	66.5	80.4	86.9	91.4	95.3	104	118
2.5 h	53.9	59.3	70.1	84.4	91.3	96.0	100	110	125
3.0 h	56.4	62.0	73.1	87.7	94.8	99.7	104	115	130
4.0 h	60.5	66.5	77.7	92.7	100	105	110	122	138
5.0 h	63.7	70.0	81.4	96.6	104	110	114	127	144
6.0 h	66.3	72.9	84.4	99.7	108	113	118	131	149
8.0 h	70.7	77.7	89.2	105	113	119	124	138	157
12.0 h	77.1	84.8	96.2	112	121	127	132	148	168
15.0 h	80.8	88.8	100	116	125	131	137	154	174
18.0 h	83.9	92.3	104	119	128	135	141	159	180
24.0 h	**89**	**98**	**109**	**124**	**134**	**141**	**147**	**166**	**188**

Duration t	Distribution of 24 h Rainfall Intensity (mm/h)								
	Retun Period T , years								
	2	3	5	10	15	20	25	50	100
5 min	138	152	180	217	235	247	258	265	300
10 min	111	122	146	177	192	202	210	219	248
15 min	93.2	103	123	151	163	171	179	187	212
30 min	64.6	71.0	85.7	105	113	119	125	133	150
45 min	50.3	55.3	66.6	81.5	88.1	92.7	96.6	104	118
1.0 h	41.6	45.7	54.9	67.1	72.5	76.2	79.5	86.0	97.4
1.5 h	31.3	34.5	41.2	50.0	54.0	56.9	59.3	64.6	73.2
2.0 h	25.4	28.0	33.2	40.2	43.4	45.7	47.7	52.2	59.1
2.5 h	21.6	23.7	28.0	33.8	36.5	38.4	40.0	44.0	49.8
3.0 h	18.8	20.7	24.4	29.2	31.6	33.2	34.7	38.2	43.2
4.0 h	15.1	16.6	19.4	23.2	25.0	26.4	27.5	30.4	34.4
5.0 h	12.7	14.0	16.3	19.3	20.9	22.0	22.9	25.4	28.8
6.0 h	11.1	12.2	14.1	16.6	18.0	18.9	19.7	21.9	24.8
8.0 h	8.8	9.7	11.2	13.1	14.1	14.9	15.5	17.3	19.6
12.0 h	6.4	7.1	8.0	9.3	10.1	10.6	11.0	12.4	14.0
15.0 h	5.4	5.9	6.7	7.7	8.3	8.8	9.1	10.3	11.6
18.0 h	4.7	5.1	5.8	6.6	7.1	7.5	7.8	8.8	10.0
24.0 h	3.7	4.1	4.5	5.2	5.6	5.9	6.1	6.9	7.8

Which gives the following short term IDF curve :

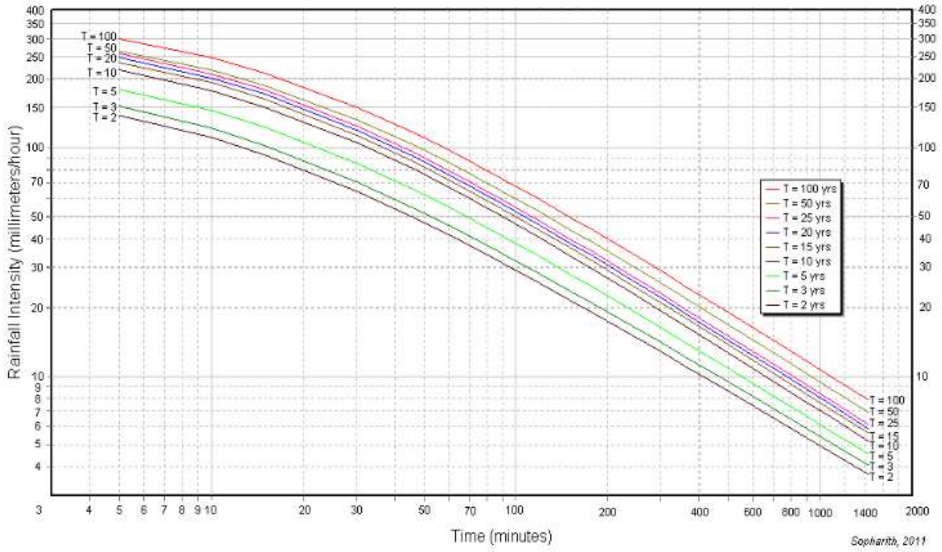


Figure 20-1 Pochentong IDF

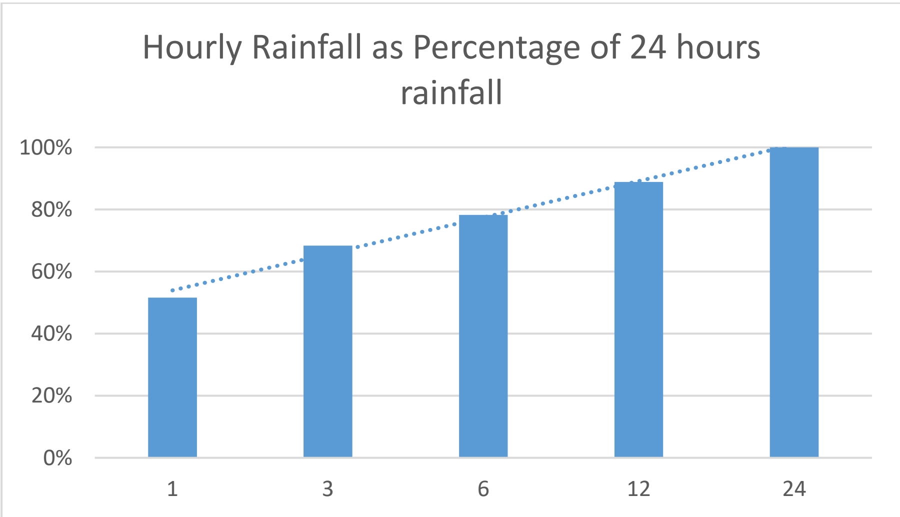


Figure 20-2 Pochentong Hourly Rainfall as Percentage of Daily

The above calculations show that the hourly rainfall is approximately 50% of the daily rainfall. This is based on actual historical rainfall data from Pochentong. These relationships were used to develop the IDF curves given in the chapters for each province.

20.3. Other Short Term Formula

There are many other short term formula that have been derived in several countries around the world. They are discussed below. They are not transferrable from one country to another as they are based on local conditions and so are extremely sit specific.

20.4. JICA Mononobe Equation

The correlation between intensity of short time rainfall, say 1 hour, 30 minutes or less, and 24 hour (daily) rain fall has been described by the formula attributed to Monobe (1983) where :

$$I_t = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^m$$

I_t is the rainfall intensity in mm/hour for a rainfall duration of t hours; R_{24} is the 24 hour rainfall and m is $^2/_3$.

The graph below shows the Mononobe equation in red versus the Pochentong data in blue.

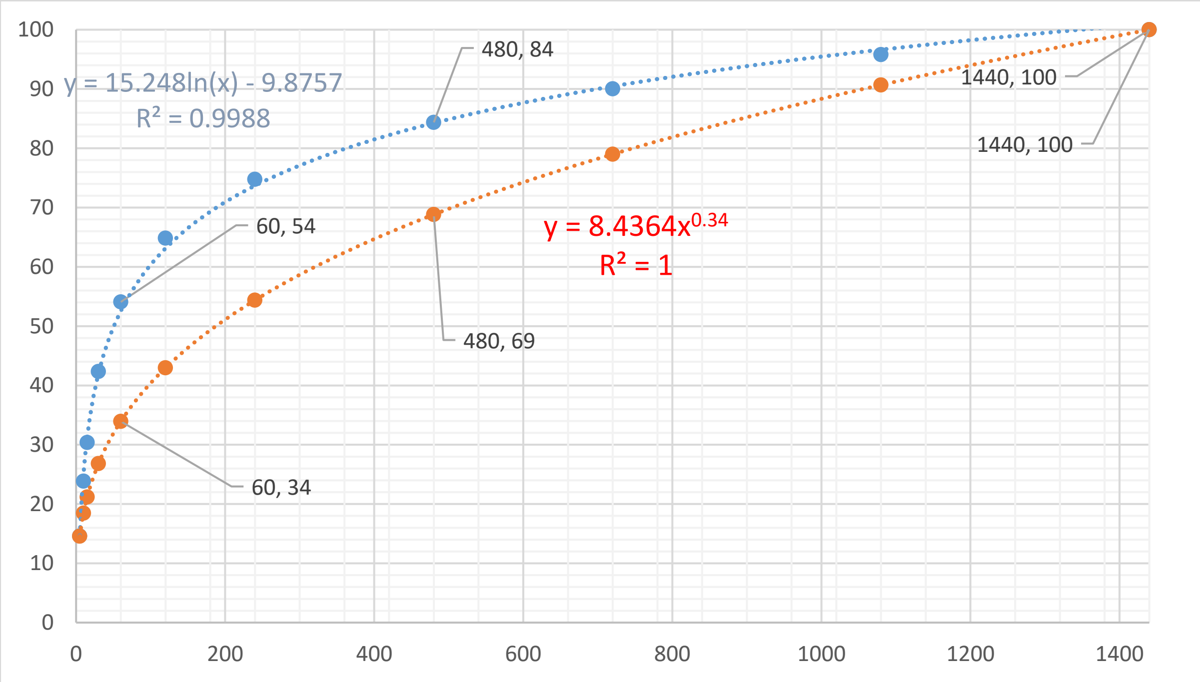


Figure 20-3 Comparison between Mononobe Equation and Pochentong

As one can see, for an hourly figure, the Monobe factor gives a figure of 34mm per hour whereas measured Pochentong data gives a figure of 54 mm per hour. This is nearly 60% higher, a significant variation.

The Monobe equation is used frequently in Cambodia in Japanese related projects. Using the Mononobe equation on Cambodian rainfall data to estimate an hourly figure for use in detailed drainage design could lead to an underestimation of nearly 40%.

20.5. Australian Standard

According to the Australia and New Zealand Unsealed Roads Manual (2015) hourly rainfall can be taken to be 4% of annual, if annual is 2,500mm or more. This means a typical hourly figure would be 4%x2,500 = 100mm/ hour.

If the annual figure is less than 2,500m then one takes a figure of 8% of annual, so if annual is 1,000 the hourly figure could be 80mm/hour. This approach take no account of daily figures.

20.6. Indian standard

In India Ram Babu et al.[23] (1979) analyzed the characteristics of 42 rainfall stations throughout India and estimated the values of the constants for different regions in India. They derived the formula :

$$i = \frac{k \times T^a}{(t+b)^n}$$

Where :

i is the intensity of rainfall, cm/hr

T is the return period in years

t is the rainfall duration in hours

k, a, b and n are the constants

The equation contains constants which depend on the geographical location of the place in question. The values were estimated to be

$k = 6.126$ $a = 0.1664$ $b = 0.5$ $n = 0.8027$

for the city of Chennai.

These can only be used in India.

20.7. French Standard

The French meteorological office publishes information on rainfall to help in drainage design known as known Montana coefficients.

The local Montana coefficients calculated by Météo-France make it possible to calculate the maximum intensity of a rain event of a definite duration or the maximum height of water to be expected for a short rainy episode. The Montana coefficients are aimed at local communities wishing to undertake remediation work. They are also of interest to research, expertise or insurance firms in the context of rainfall studies.

The Montana coefficients are a reference for sizing structures intended to evacuate or channel water. The Montana coefficients make it possible to know, for a given rain duration, the maximum water height expected for each of the following return periods: 5 years, 10 years, 20 years, 30 years. They are applied in the following formula .

$$h(t) = a \times t^{(1-b)}$$

Durée de retour	a	b
5 ans	10.874	0.779
10 ans	15.096	0.803
20 ans	20.219	0.825
30 ans	23.79	0.838
50 ans	28.93	0.852
100 ans	37.379	0.872

[23] *Ram Babu, Tejwani, K. K., Agrawal, M. C. &Bhusan, L. S. (1979) - Rainfall intensity-duration-return period equations & nomographs of India, CSWCRTI, ICAR, Dehradun, India.*

The Montana coefficients are available on more than 80 rainfall gauging stations for the whole of metropolitan France. They can only be applied in France.

20.8. Measured Hourly Rainfall at stations in Cambodia

232. In order to develop a meaningful strategy for the provinces real measured short term data for Cambodia was obtained from MOWRAM. This data was obtained from Automatic Weather Stations operated by MOWRAM that were originally installed with support from ADB.

233. Data for 11provinces is shown below for the maximum hourly figures recorded at each of the stations. These data have been collected over the past 4 years. Provinces around Tonle Sap are marked in grey and other provinces in blue.

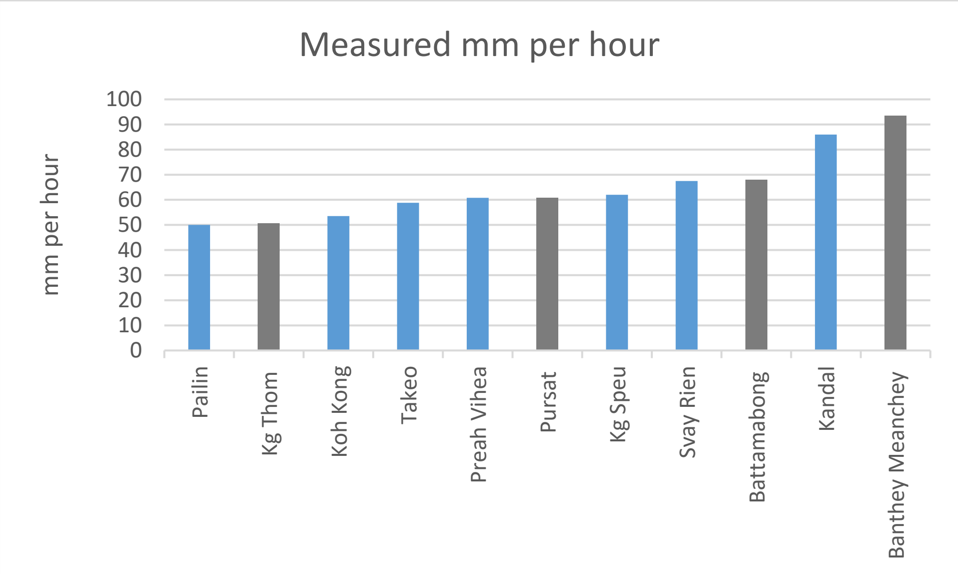


Figure 20-4 Variation in 1 hour maximum rainfall with Location

234. These figures represent the maximum hourly rainfall recorded at each station. There are not enough years of data to carry out extreme value analysis, as is required to produce IDF curves, but nonetheless the data is extremely valuable.

235. As can be seen there is significant variation across the country with some provinces experiencing almost twice the short term intensity of other provinces.

236. Figures for Kampong Thom indicate 50mm per hour. Figures for Banthey Meanchey indicate over 90mm per hour. The former figure (50mm/hr) is typical of a heavy downpour and the latter figure (90mm/hr) signifies extremely heavy rain.

237. Extremely heavy rain is usually the descriptor for rainfall of 200mm / day or higher. If 90mm is falling in one hour then the factor of 50% applies, that is to say it is very plausible that 50% of a daily rainfall occurs in one hour. This is supported by the measured data from Pochentong Airport.

238. It is recommended that if daily rainfall is known then a figure of 50% of the daily rainfall be taken as the peak hourly rainfall.

239. It is also recommended that in the absence of any rainfall data a figure of 50mm/hr be taken as a heavy rainstorm and a figure of 100mm/hr be taken as an extreme weather event. These figures can be used in drainage design.

21. DELTA METHOD IN RAINFALL PROJECTIONS

21.1. NASA NEX Data

240. The NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) were developed in support of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5). The NEX-GDDP dataset includes RCP 4.5 and RCP 8.5 and gives daily maximum temperature, minimum temperature, and precipitation for the periods from 1950 through 2100. The data covers the entire earth at a resolution of 0.25 degrees (~25 km x 25 km) and has been used in this report. Data produced for Kampong Chhnang is given below.

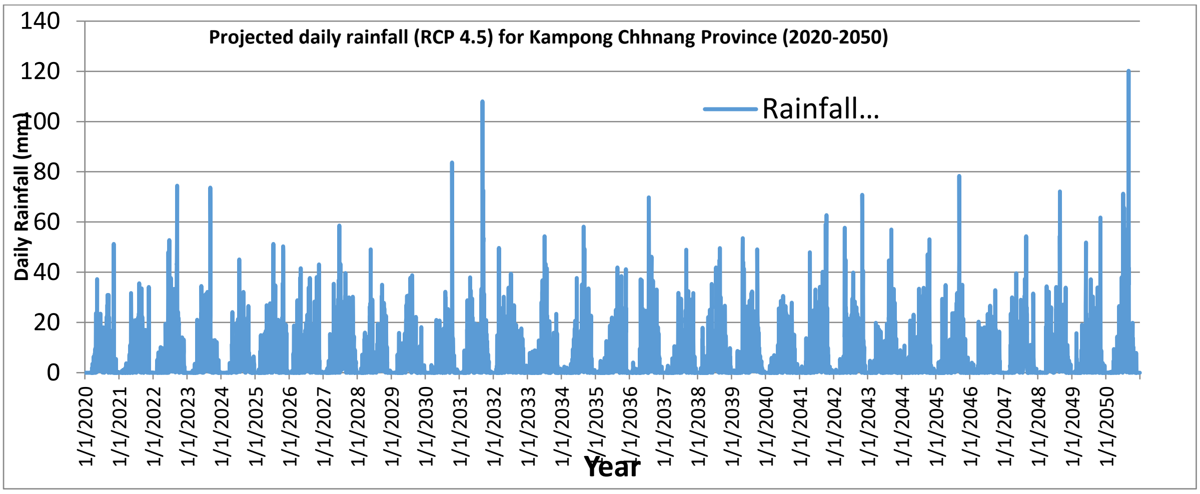


Figure 21-1 Projected daily rainfall (RCP 4.5) for Kampong Chhnang Province (2020-2050)

The above shows all daily rainfall. From this one can extract maximum daily rain fall for each year as shown below.

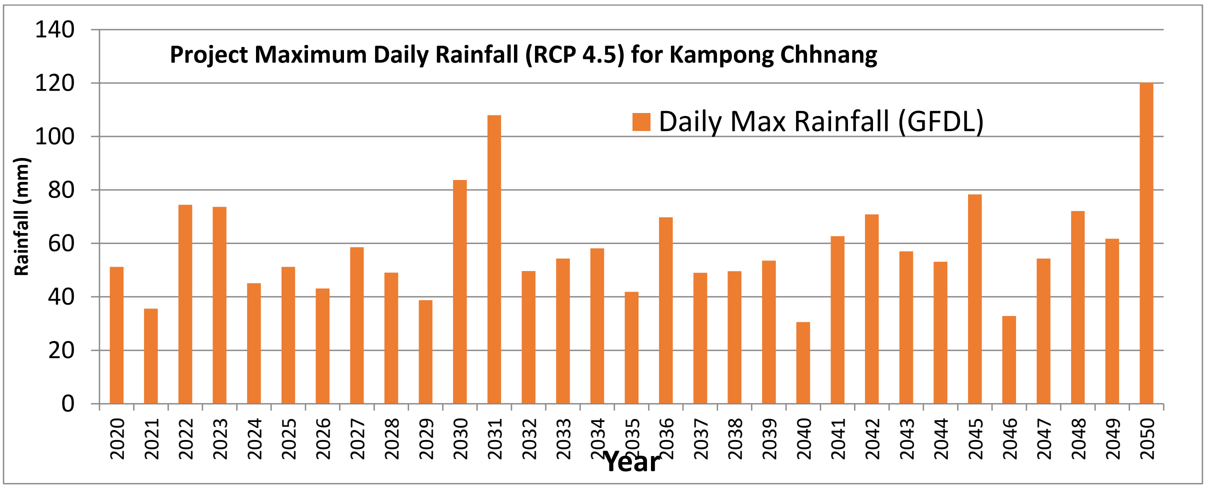


Figure 21-2 Project Maximum Daily Rainfall (RCP 4.5) for Kampong Chhnang

This can be for selected RCP values. Below is shown future temperature variations for Kampong Chhnang for RCP 4.5 and 8.5.

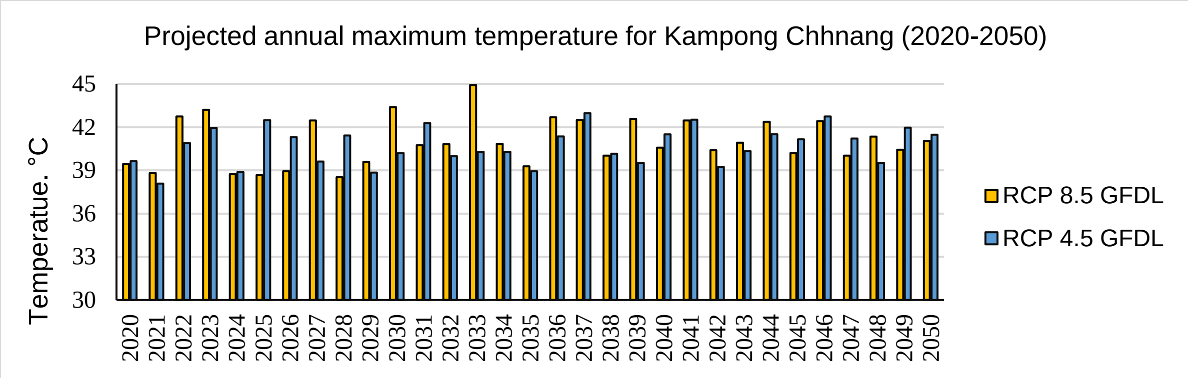


Figure 21-3 Projected annual maximum temperature for Kampong Chhnang (2020-2050)

241. Data produced for Pursat for RCP 4.5 and RCP 8.5 and daily maximum precipitation and temperature for the periods from 1950 through 2100 is given below.

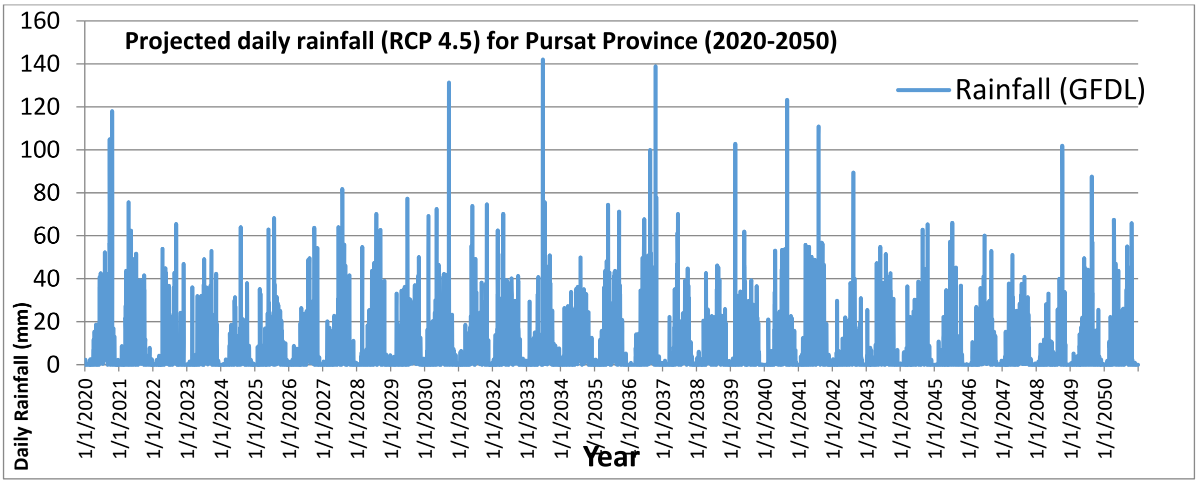


Figure 21-4 Projected daily rainfall (RCP 4.5) for Pursat Province (2020-2050)

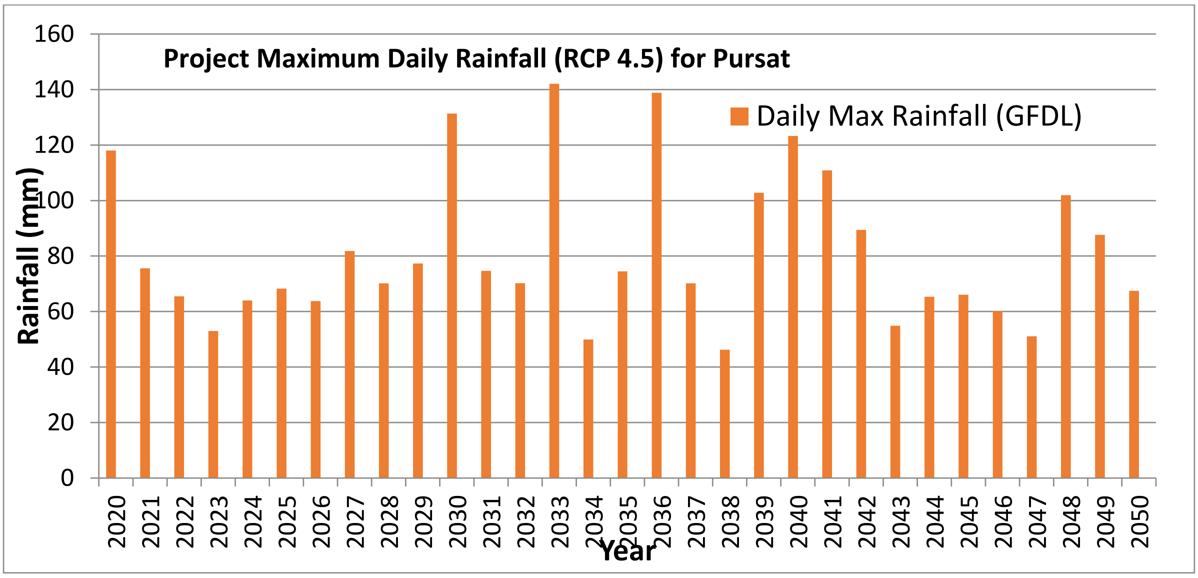


Figure 21-5 Project Maximum Daily Rainfall (RCP 4.5) for Pursat

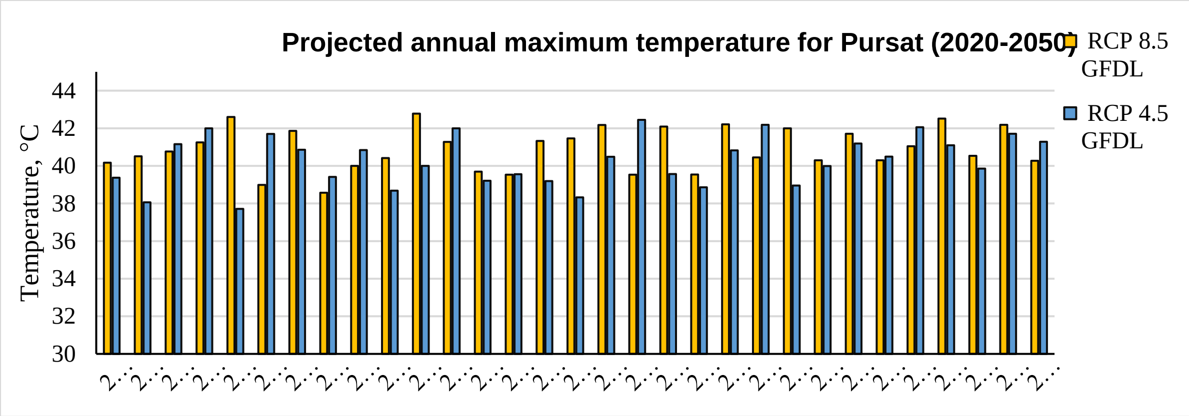


Figure 21-6 Projected annual maximum temperature for Pursat (2020-2050)

21.2. Application of the Delta Method

The NASA NEX data set has been used to "hindcast" precipitation data for 1985 to 2005 and "forecast" precipitation data for 2040 to 2060. The data produced were then analysed for annual maximum daily values. These were then compared and the difference between the two determined. This is the "Delta" function.

This Delta difference is shown below for each province for RCPs 4.5 and 8.5, time durations from 5 minutes to 24 hours and return periods of 2 to 100 years.

This factor should then be added on to the existing IDF values to give the anticipated precipitation figures in the future under the two RCP scenarios, 4.5 and 8.5.

21.3. Projected IDFs for RCP 4.5

Delta figures for RCP 4.5 are given below.

Table 21-1 Delta Functions for All 6 Provinces for RCP 4.5

Delta IDF for Kampon Chhnang Province										
Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
		Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
5	**min**	7%	5%	3%	2%	0.25%	-1.30%	-1.73%	-2.86%	-3.78%
10	**min**	7%	5%	3%	2%	0.25%	-1.30%	-1.73%	-2.86%	-3.78%
15	**min**	7%	5%	3%	2%	0.25%	-1.30%	-1.73%	-2.86%	-3.78%
30	**min**	7%	5%	3%	2%	0.25%	-1.30%	-1.73%	-2.86%	-3.78%
1	**h**	7%	5%	3%	2%	0.25%	-1.30%	-1.73%	-2.86%	-3.78%
2	**h**	7%	5%	3%	2%	0.25%	-1.30%	-1.73%	-2.86%	-3.78%
4	**h**	7%	5%	3%	2%	0.25%	-1.30%	-1.73%	-2.86%	-3.78%
8	**h**	7%	5%	3%	2%	0.25%	-1.30%	-1.73%	-2.86%	-3.78%
12	**h**	7%	5%	3%	2%	0.25%	-1.30%	-1.73%	-2.86%	-3.78%
18	**h**	7%	5%	3%	2%	0.25%	-1.30%	-1.73%	-2.86%	-3.78%
24	**h**	7%	5%	3%	2%	0.25%	-1.30%	-1.73%	-2.86%	-3.78%

Delta IDF for Pursat Province										
Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
		Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
5	min	-1%	-3%	-4%	-5%	-6%	-8%	-8%	-9%	-10%
10	min	-1%	-3%	-4%	-5%	-6%	-8%	-8%	-9%	-10%
15	min	-1%	-3%	-4%	-5%	-6%	-8%	-8%	-9%	-10%
30	min	-1%	-3%	-4%	-5%	-6%	-8%	-8%	-9%	-10%
1	h	-1%	-3%	-4%	-5%	-6%	-8%	-8%	-9%	-10%
2	h	-1%	-3%	-4%	-5%	-6%	-8%	-8%	-9%	-10%
4	h	-1%	-3%	-4%	-5%	-6%	-8%	-8%	-9%	-10%
8	h	-1%	-3%	-4%	-5%	-6%	-8%	-8%	-9%	-10%
12	h	-1%	-3%	-4%	-5%	-6%	-8%	-8%	-9%	-10%
18	h	-1%	-3%	-4%	-5%	-6%	-8%	-8%	-9%	-10%
24	h	-1%	-3%	-4%	-5%	-6%	-8%	-8%	-9%	-10%

Delta IDF for Battambang Province										
Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
		Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
5	min	-16%	-19%	-20%	-21%	-24%	-26%	-26%	-28%	-29%
10	min	-16%	-19%	-20%	-21%	-24%	-26%	-26%	-28%	-29%
15	min	-16%	-19%	-20%	-21%	-24%	-26%	-26%	-28%	-29%
30	min	-16%	-19%	-20%	-21%	-24%	-26%	-26%	-28%	-29%
1	h	-16%	-19%	-20%	-21%	-24%	-26%	-26%	-28%	-29%
2	h	-16%	-19%	-20%	-21%	-24%	-26%	-26%	-28%	-29%
4	h	-16%	-19%	-20%	-21%	-24%	-26%	-26%	-28%	-29%
8	h	-16%	-19%	-20%	-21%	-24%	-26%	-26%	-28%	-29%
12	h	-16%	-19%	-20%	-21%	-24%	-26%	-26%	-28%	-29%
18	h	-16%	-19%	-20%	-21%	-24%	-26%	-26%	-28%	-29%
24	h	-16%	-19%	-20%	-21%	-24%	-26%	-26%	-28%	-29%

Delta IDF for Serei Sophon Province										
Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
		Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
5	min	-8%	3%	8%	11%	17%	20%	21%	24%	25%
10	min	-8%	3%	8%	11%	17%	20%	21%	24%	25%
15	min	-8%	3%	8%	11%	17%	20%	21%	24%	25%
30	min	-8%	3%	8%	11%	17%	20%	21%	24%	25%
1	h	-8%	3%	8%	11%	17%	20%	21%	24%	25%
2	h	-8%	3%	8%	11%	17%	20%	21%	24%	25%
4	h	-8%	3%	8%	11%	17%	20%	21%	24%	25%
8	h	-8%	3%	8%	11%	17%	20%	21%	24%	25%
12	h	-8%	3%	8%	11%	17%	20%	21%	24%	25%
18	h	-8%	3%	8%	11%	17%	20%	21%	24%	25%
24	h	-8%	3%	8%	11%	17%	20%	21%	24%	25%

Delta IDF for Siem Reap Province										
Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
		Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
5	min	-23%	-27%	-29%	-31%	-34%	-37%	-38%	-39%	-41%
10	min	-23%	-27%	-29%	-31%	-34%	-37%	-38%	-39%	-41%
15	min	-23%	-27%	-29%	-31%	-34%	-37%	-38%	-39%	-41%
30	min	-23%	-27%	-29%	-31%	-34%	-37%	-38%	-39%	-41%
1	h	-23%	-27%	-29%	-31%	-34%	-37%	-38%	-39%	-41%
2	h	-23%	-27%	-29%	-31%	-34%	-37%	-38%	-39%	-41%
4	h	-23%	-27%	-29%	-31%	-34%	-37%	-38%	-39%	-41%
8	h	-23%	-27%	-29%	-31%	-34%	-37%	-38%	-39%	-41%
12	h	-23%	-27%	-29%	-31%	-34%	-37%	-38%	-39%	-41%
18	h	-23%	-27%	-29%	-31%	-34%	-37%	-38%	-39%	-41%
24	h	-23%	-27%	-29%	-31%	-34%	-37%	-38%	-39%	-41%

Delta IDF for Kampong Thom Province										
Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
		Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
5	min	7%	10%	12%	13%	15%	17%	17%	18%	19%
10	min	7%	10%	12%	13%	15%	17%	17%	18%	19%
15	min	7%	10%	12%	13%	15%	17%	17%	18%	19%
30	min	7%	10%	12%	13%	15%	17%	17%	18%	19%
1	h	7%	10%	12%	13%	15%	17%	17%	18%	19%
2	h	7%	10%	12%	13%	15%	17%	17%	18%	19%
4	h	7%	10%	12%	13%	15%	17%	17%	18%	19%
8	h	7%	10%	12%	13%	15%	17%	17%	18%	19%
12	h	7%	10%	12%	13%	15%	17%	17%	18%	19%
18	h	7%	10%	12%	13%	15%	17%	17%	18%	19%
24	h	7%	10%	12%	13%	15%	17%	17%	18%	19%

21.4. Projected IDFs for RCP 8.5

Delta figures for RCP 8.5 are given below.

Table 21-2 Delta Functions for All 6 Provinces for RCP 8.5

Delta IDF for Kampong Chhnang Province										
Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
		Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
5	min	18%	18%	18%	17%	17%	17%	17%	17%	16%
10	min	18%	18%	18%	17%	17%	17%	17%	17%	16%
15	min	18%	18%	18%	17%	17%	17%	17%	17%	16%
30	min	18%	18%	18%	17%	17%	17%	17%	17%	16%
1	h	18%	18%	18%	17%	17%	17%	17%	17%	16%
2	h	18%	18%	18%	17%	17%	17%	17%	17%	16%
4	h	18%	18%	18%	17%	17%	17%	17%	17%	16%
8	h	18%	18%	18%	17%	17%	17%	17%	17%	16%
12	h	18%	18%	18%	17%	17%	17%	17%	17%	16%
18	h	18%	18%	18%	17%	17%	17%	17%	17%	16%
24	h	18%	18%	18%	17%	17%	17%	17%	17%	16%

Delta IDF for Pursat Province										
Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
		Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
5	min	10%	17%	20%	22%	26%	29%	30%	32%	34%
10	min	10%	17%	20%	22%	26%	29%	30%	32%	34%
15	min	10%	17%	20%	22%	26%	29%	30%	32%	34%
30	min	10%	17%	20%	22%	26%	29%	30%	32%	34%
1	h	10%	17%	20%	22%	26%	29%	30%	32%	34%
2	h	10%	17%	20%	22%	26%	29%	30%	32%	34%
4	h	10%	17%	20%	22%	26%	29%	30%	32%	34%
8	h	10%	17%	20%	22%	26%	29%	30%	32%	34%
12	h	10%	17%	20%	22%	26%	29%	30%	32%	34%
18	h	10%	17%	20%	22%	26%	29%	30%	32%	34%
24	h	10%	17%	20%	22%	26%	29%	30%	32%	34%

Delta IDF for Battambang Province										
Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
		Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
5	min	-0.45%	3%	4%	5%	8%	9%	10%	11%	12%
10	min	-0.45%	3%	4%	5%	8%	9%	10%	11%	12%
15	min	-0.45%	3%	4%	5%	8%	9%	10%	11%	12%
30	min	-0.45%	3%	4%	5%	8%	9%	10%	11%	12%
1	h	-0.45%	3%	4%	5%	8%	9%	10%	11%	12%
2	h	-0.45%	3%	4%	5%	8%	9%	10%	11%	12%
4	h	-0.45%	3%	4%	5%	8%	9%	10%	11%	12%
8	h	-0.45%	3%	4%	5%	8%	9%	10%	11%	12%
12	h	-0.45%	3%	4%	5%	8%	9%	10%	11%	12%
18	h	-0.45%	3%	4%	5%	8%	9%	10%	11%	12%
24	h	-0.45%	3%	4%	5%	8%	9%	10%	11%	12%

Delta IDF for Serei Saophon Province										
Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
		Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
5	min	7%	9%	9%	9%	10%	11%	11%	11%	12%
10	min	7%	9%	9%	9%	10%	11%	11%	11%	12%
15	min	7%	9%	9%	9%	10%	11%	11%	11%	12%
30	min	7%	9%	9%	9%	10%	11%	11%	11%	12%
1	h	7%	9%	9%	9%	10%	11%	11%	11%	12%
2	h	7%	9%	9%	9%	10%	11%	11%	11%	12%
4	h	7%	9%	9%	9%	10%	11%	11%	11%	12%
8	h	7%	9%	9%	9%	10%	11%	11%	11%	12%
12	h	7%	9%	9%	9%	10%	11%	11%	11%	12%
18	h	7%	9%	9%	9%	10%	11%	11%	11%	12%
24	h	7%	9%	9%	9%	10%	11%	11%	11%	12%

Delta IDF for Siem Reap Province										
Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
		Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
5	**min**	0.44%	3%	5%	6%	8%	9%	9%	10%	11%
10	**min**	0.44%	3%	5%	6%	8%	9%	9%	10%	11%
15	**min**	0.44%	3%	5%	6%	8%	9%	9%	10%	11%
30	**min**	0.44%	3%	5%	6%	8%	9%	9%	10%	11%
1	**h**	0.44%	3%	5%	6%	8%	9%	9%	10%	11%
2	**h**	0.44%	3%	5%	6%	8%	9%	9%	10%	11%
4	**h**	0.44%	3%	5%	6%	8%	9%	9%	10%	11%
8	**h**	0.44%	3%	5%	6%	8%	9%	9%	10%	11%
12	**h**	0.44%	3%	5%	6%	8%	9%	9%	10%	11%
18	**h**	0.44%	3%	5%	6%	8%	9%	9%	10%	11%
24	**h**	0.44%	3%	5%	6%	8%	9%	9%	10%	11%

Delta IDF for Kampong Thom Province										
Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
		Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
5	**min**	19%	22%	24%	25%	28%	29%	30%	31%	32%
10	**min**	19%	22%	24%	25%	28%	29%	30%	31%	32%
15	**min**	19%	22%	24%	25%	28%	29%	30%	31%	32%
30	**min**	19%	22%	24%	25%	28%	29%	30%	31%	32%
1	**h**	19%	22%	24%	25%	28%	29%	30%	31%	32%
2	**h**	19%	22%	24%	25%	28%	29%	30%	31%	32%
4	**h**	19%	22%	24%	25%	28%	29%	30%	31%	32%
8	**h**	19%	22%	24%	25%	28%	29%	30%	31%	32%
12	**h**	19%	22%	24%	25%	28%	29%	30%	31%	32%
18	**h**	19%	22%	24%	25%	28%	29%	30%	31%	32%
24	**h**	19%	22%	24%	25%	28%	29%	30%	31%	32%

These results are discussed in the section on Provincial Strategies below.

22. PROVINCIAL STRATEGIES FOR CLIMATE RESILIENCE

22.1. Spatial Variations in Daily Rainfall Across Cambodia

242. There are three main hydrological zones in Cambodia where weather patterns vary, that is :

- Around Tonle Sap Lake in the catchment area bounded by the Dangrek escarpment to the north and the Cardamon mountains to the west.
- Along the Mekong river from the Laos border to the confluence with Tonle Sap river in Phnom Penh
- The coastal strip bounded by the south west facing Cardamon mountains

243. Rainfall patterns vary across the country and MOWRAM have kept records in 19 provinces. These are shown below.[24] MOWRAM keep daily (24 hour records) going back over 30 years. From these the Intensity Duration Frequency (IDF) curves for various Annual Return Intervals from 1 in 2 years to 1 in 100 years have been produced. A full set of these IDF curves for each province is included in Annex 3. These can be referred to by provincial authorities as some of provinces are affected by rainfall in adjacent upstream provinces.

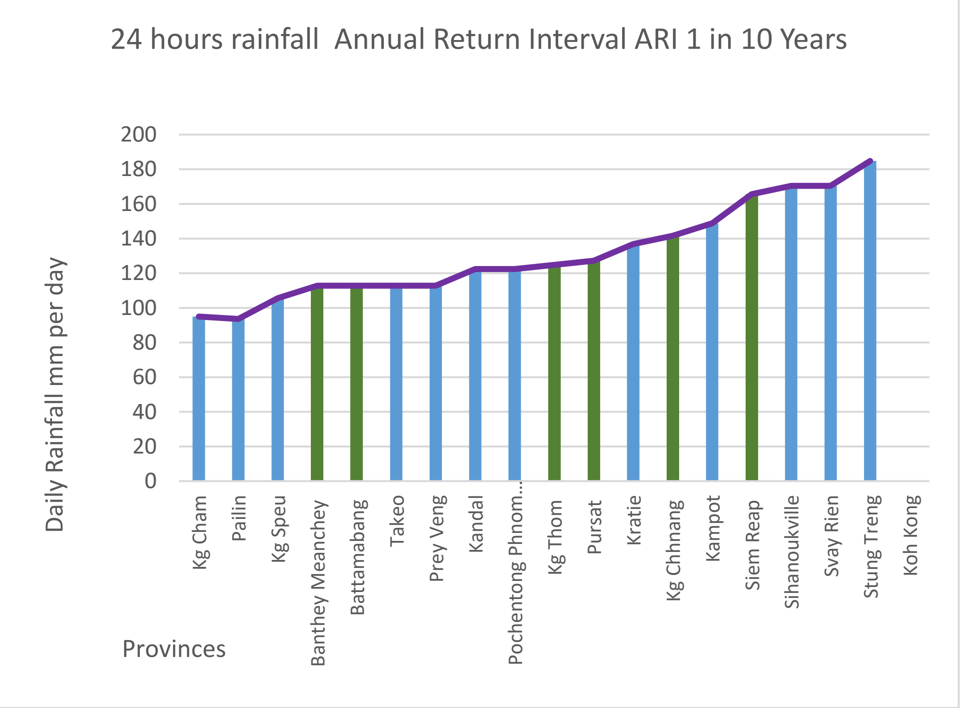


Figure 22-1 Variation in 24 hour IDF with Province

244. As can be seen there is a definite pronounced trend across the country with some provinces receiving twice as much intensity of rainfall as other. When designing infrastructure, the IDF curve for each province should be selected.

[24] Koh Kong is an outlier at 298 mm / day and for the purposes of this study has been omitted.

22.2. Spatial Variations in Daily Rainfall Across Tonle Sap Provinces

245. As a subset of the data given above the 6 provinces around Tonle Sap Lake have been examined. Again the 24 hour rainfall for a 1 in 10 year event has been presented as given below.

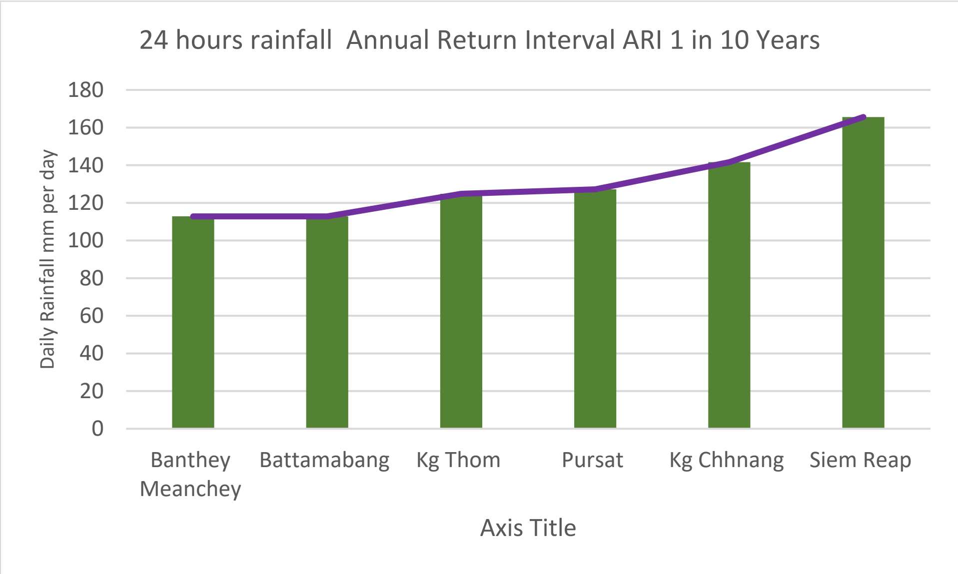


Figure 22-2 Variation in 24 hour IDF with Provinces around Tonle Sap

246. As can be seen there is a distinct variation across Tonle Sap with a difference of 60% between different locations.

The analysis of the historical data for each provincial capital has been compared in an IDF format and shows a distinct pattern across Tonle Sap lake.

Table 22-1 All 6 Provinces 1 hour and 24 hours

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
1hr	KgChg	48.3	56.4	61.6	65.4	77	88	91	97	107
	Pursat	44.2	51.3	55.8	59.2	69	79	82	87	96
	Batt	43.6	48.4	51.6	53.9	61	67	69	73	79
	BTMy	43.2	48.2	51.4	53.7	61	67	70	73	79
	SR	54.5	64.5	70.9	75.7	90	103	107	115	128
	KT	49.8	54.8	58.1	60.5	68	74	76	80	86
24hr	KgChg	3.7	4.3	4.7	5.0	5.9	6.7	7.0	7.8	8.6
	Pursat	3.4	4.0	4.3	4.6	5.3	6.1	6.3	7.0	7.7
	Batt	3.4	3.7	4.0	4.2	4.7	5.2	5.3	5.8	6.3
	BTMy	3.3	3.7	4.0	4.1	4.7	5.2	5.4	5.9	6.4
	SR	4.2	5.0	5.5	5.8	6.9	7.9	8.3	9.3	10.3
	KTh	3.8	4.2	4.5	4.7	5.2	5.7	5.9	6.4	6.9

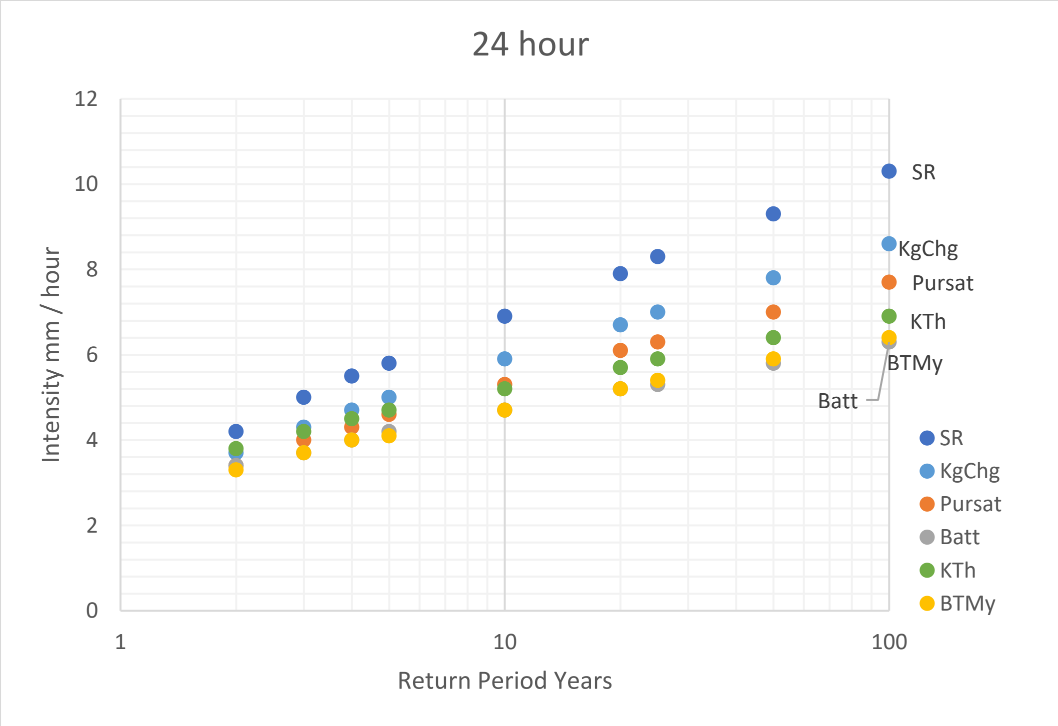


Figure 22-3 Variation in 24 hour IDF with Location

247. There is a distinct clustering of the precipitation among the towns. The lowest rainfall occurs in the towns and provinces of Serei Sisophon and Battambang. The medium rainfall values occur in Pursat and Stung Saen. The highest rainfall occurs in Siem Reap and Kampong Chhnang. This is shown in the figure below.

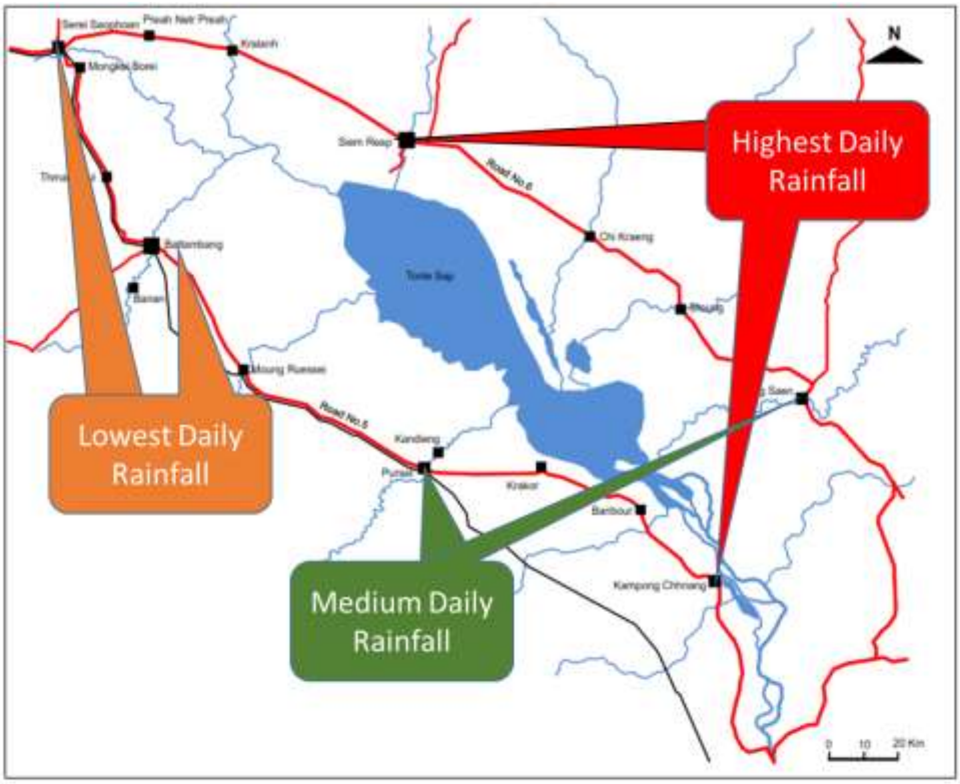


Figure 22-4 Similarities and Differences in Daily Rainfall with Location

248. This variability is thought to be due to the following reasons :

- Siem Reap is under the orographic influence of the Dangrek Escarpment as is Kampong Chhnang under the influence of Mount Aoral and the Cardamon Mountains
- Battamabang and Serei Sisophon are close by to each other in a basically flat plain area
- Pursat and Kampong Thom are on the same latitude facing each other across the lake and share similar weather patterns.

22.3. Spatial Variations in Derived Hourly Rainfall Across Cambodia

249. For design engineers it is vital to know what form of precipitation data to follow. In particular urban designers need information on hourly or even 15 minutes rainfall in order to design urban drainage where there are large areas of impermeable surfaces such as roads, car parks, roofs etc. One can apply short term correction factors to give the theoretical values shown in the figure below (Figure 22-5) but as shown in Section 20 there are large variations in theoretical correction factors.

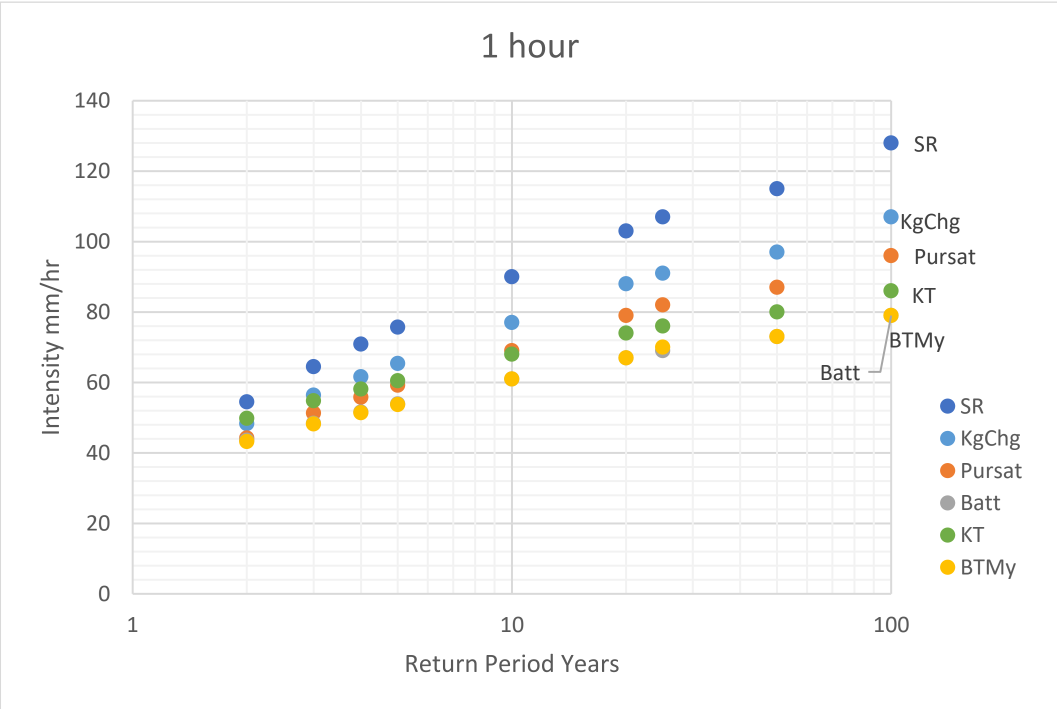


Figure 22-5 Variation in 1 hour IDF with Location

The figures above should be used with caution.

22.4. Spatial Variations in Measured Hourly Rainfall Across Cambodia

250. As discussed in Section 20.8 real measured short term data for Cambodia was obtained from MOWRAM. Provinces around Tonle sap are marked in grey and other provinces in blue.

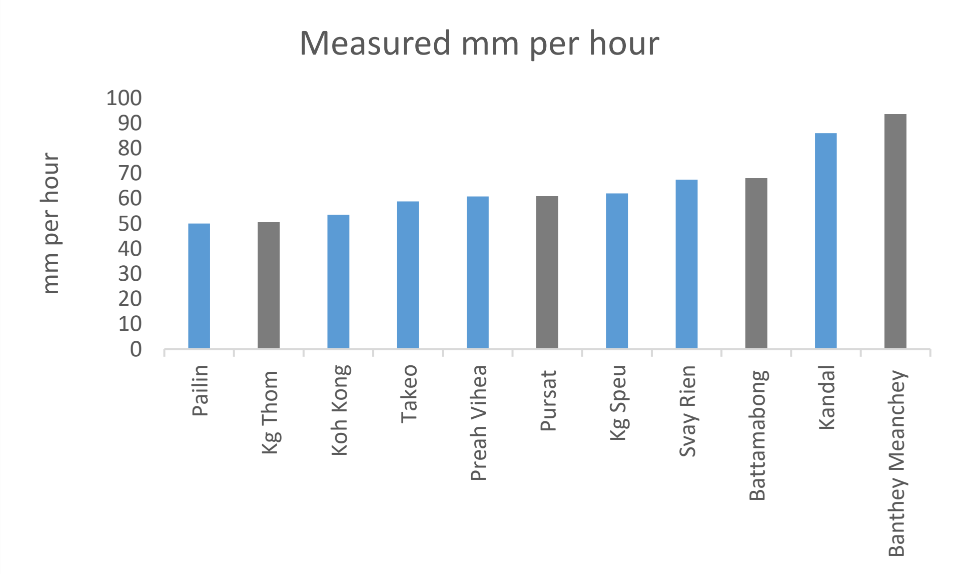


Figure 22-6 Variation in 1 hour maximum rainfall with Location

251. Some provinces experience almost twice the short term rainfall intensity of other provinces.

22.5. Spatial Variations in Hourly Rainfall Across Tonle Sap Provinces

252. Only 4 provinces around Tonle Sap have actual automatic measuring stations for short term rainfall. They are shown below. There is an 80% variation in maximum hourly rainfall from one side of the lake to the other.

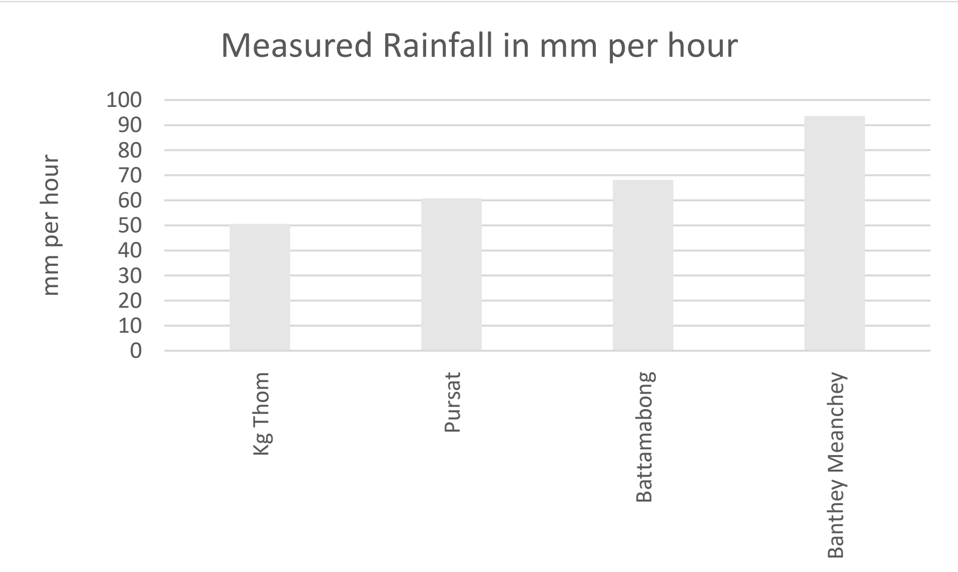


Figure 22-7 Provinces around Tonle Sap 1 hour maximum rainfall

22.6. Implications in Use of Historical Rainfall Data

253. It should be noted that annual data, daily data and hourly data can give contradictory results for the same location. As shown in the figure below (Figure 22-8) for hourly data when compared with Figure 22-4 for daily data, although Battambang had lowest daily rainfall, it had highest hourly rainfall. This suggests the Battambang experiences short duration but high intensity rain storms.

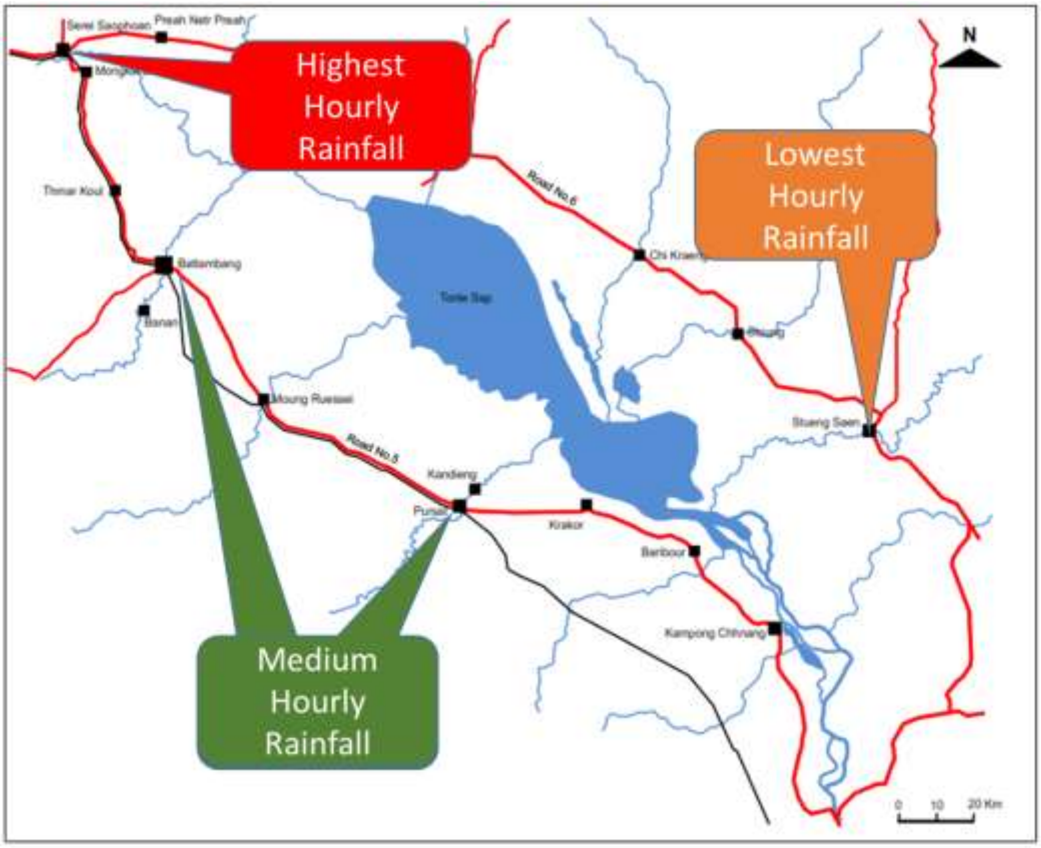


Figure 22-8 Provinces around Tonle Sap 1 hour maximum rainfall

254. The main parameter of interest is hourly data and where possible real measured data should be used in calculations.
Climate Change Variability

22.7. Climate Change Projections t

255. The table below shows the correction factors that must be added on to or subtracted from any IDF values used in drainage design to allow for climate change.

22.7.1. RCP 4.5

256. The correction factors for RCP4.5 are shown below.

Table 22-2 Delta Functions RCP4.5

Delta IDF for RCP 4.5									
Location	Intensity-Duration-Frequency (mm/hrs)								
	Return Period, T								
	2	3	4	5	10	20	25	50	100
	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
Kampong Chhnang	7%	5%	3%	2%	0%	-1%	-2%	-3%	-4%
Pursat	-1%	-3%	-4%	-5%	-6%	-8%	-8%	-9%	-10%
Battambang	-16%	-19%	-20%	-21%	-24%	-26%	-26%	-28%	-29%
Serei Sisophon	-8%	3%	8%	11%	17%	20%	21%	24%	25%
Siem Reap	-23%	-27%	-29%	-31%	-34%	-37%	-38%	-39%	-41%
Kampong Thom	7%	10%	12%	13%	15%	17%	17%	18%	19%

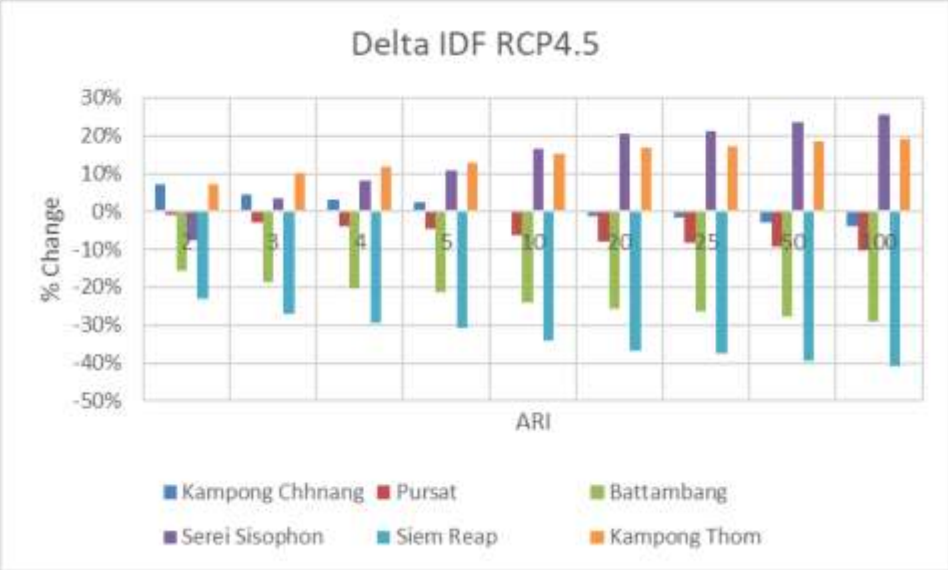


Figure 22-9 Delta Function Corrections under RCP4.5

257. The figures show that for a common design event say a 1 in 10 year storm in the future under RCP4.5 which is an optimistic scenario, for :

- Kampong Chhnang; precipitation will remain the same
- Pursat: precipitation will go down by 6%
- Battambang; precipitation will go down by 26%
- Serei Sisophon; precipitation will go up by 26%
- Siem Reap; precipitation will go down by 34%
- Kampong Thom; precipitation will go up by 15%

258. Also for an extreme event say a 1 in 100 year storm in the future under RCP4.5 which is an optimistic scenario, for :

- Kampong Chhnang; precipitation will go down by 4%
- Pursat; precipitation will go down by 10%
- Battambang; precipitation will go down by 29%
- Serei Sisophon; precipitation will go up by 25%
- Siem Reap; precipitation will go down by 41%
- Kampong Thom; precipitation will go up by 19%

22.7.2. RCP8.5

259. The correction factors for RCP8.5 are shown below.

Table 22-3 Delta Function Corrections under RCP8.5

Delta IDF for RCP 8.5									
Location	Intensity-Duration-Frequency (mm/hrs)								
	Return Period, T								
	2	3	4	5	10	20	25	50	100
	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%	Delta%
Kampong Chhnang	18%	18%	18%	17%	17%	17%	17%	17%	16%
Pursat	10%	17%	20%	22%	26%	29%	30%	32%	34%
Battambang	-0.45%	3%	4%	5%	8%	9%	10%	11%	12%
Serei Sisophon	7%	9%	9%	9%	10%	11%	11%	11%	12%
Siem Reap	0.44%	3%	5%	6%	8%	9%	9%	10%	11%
Kampong Thom	19%	22%	24%	25%	28%	29%	30%	31%	32%

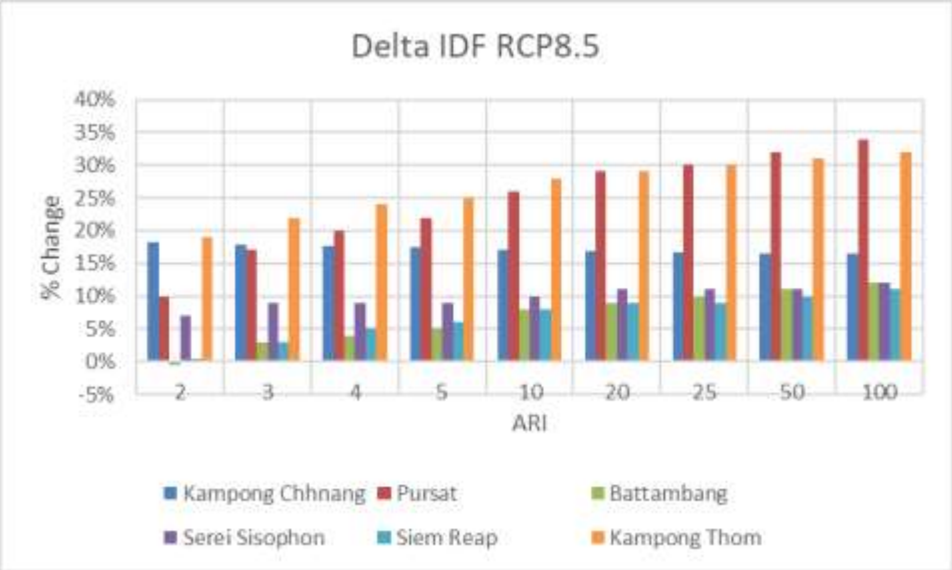


Figure 22-10 Delta Function Corrections under RCP8.5

260. The figures show that for a common design event say a 1 in 10 year storm in the future under RCP8.5 which is a pessimistic scenario, for :

- Kampong Chhnang; precipitation will go up by 17%
- Pursat: precipitation will go up by 26%
- Battambang; precipitation will go up by 8%
- Serei Sisophon; precipitation will go up by 10%
- Siem Reap; precipitation will go up by 8%
- Kampong Thom; precipitation will go up by 28%

261. Also for an extreme event say a 1 in 100 year storm in the future under RCP8.5 which is an pessimistic scenario, for :

- Kampong Chhnang; precipitation will go up by 16%
- Pursat; precipitation will go up by 34%
- Battambang; precipitation will go up by 12%
- Serei Sisophon; precipitation will go up by 12%
- Siem Reap; precipitation will go up by 11%
- Kampong Thom; precipitation will go up by 32%

262. As this is a pessimistic scenario increases in short term precipitation can be expected. All site will experience an increase in short storm intensity, by a maximum of 34%.

This factor should be applied in detailed design.

22.8. Recommended Actins in Provincial Strategy

22.8.1. Run Off Calculations

263. If runoff calculations are to be made then for areas greater than 1km2 do not use the Rational Method but use the Generalised Tropical Flood Model (GTFM) derived by Fiddes and Watkins 1984.

22.8.2. Daily Rainfall

264. Where calculations for drainage are to be based on daily rainfall figures use the IDF curves given in Annex 3.

22.8.3. Hourly Rainfall

265. If hourly data is known then it should be used. If only daily rainfall is known then it is recommended that a figure of 50% of the daily rainfall be taken as the peak hourly rainfall. This is conservative.

22.8.4. Flood Protection

266. For design of flood protection the 1 in 100 year storm event should be taken and 0.25 metres be added to the height for freeboard. To this should be added another 0.25metres to allow for increased flooding under RCP8.5 in 2050.

22.8.5. Landfills

267. Landfills must not be located in flood prone areas. The MPWT software FRMI gives indications of flood characterisation of roads. As all landfills have approach roads the nearest road flood risk category can be used as an indicator.

268. Landfill cells must have rainfall run off drains when completed. These should be designed to cope with a 1 in 20 year rain storm. An increment of 30% should be added to this rainfall figure to allow for RCP8.5 in 2050.

22.8.6. Roads

269. National highways should be designed to withstand a 1 in 100 year event. The provincial IDF should be consulted and the design flood plus 0.5 metres taken as the climate resilient road design.

270. Provincial highways should be designed to a 1 in 20 year flood height with 0.25 metre added to this height as freeboard.

22.8.7. Waste Water Treatment Plants

271. Waste water treatment plants based on the Lagoon Principle must not be located in flood prone areas. The MPWT software FRMI gives indications of flood characterisation of roads. As lagoons have approach roads so that septic tank emptying trucks can approach them, the nearest road flood risk category can be used as an indicator.

22.8.8. Cost of Climate Resilience Defences

272. Work so far indicates that the incremental costs of rendering infrastructure climate resilient is around 3% of the overall capital cost.

22.8.9. Workshop

273. A flow chart for implementation of the Climate Resilience Strategy is given. (Figure 22-11) This strategy was delivered to the Provincial Government representatives in a workshop and well received. Details are given in Annex 6.

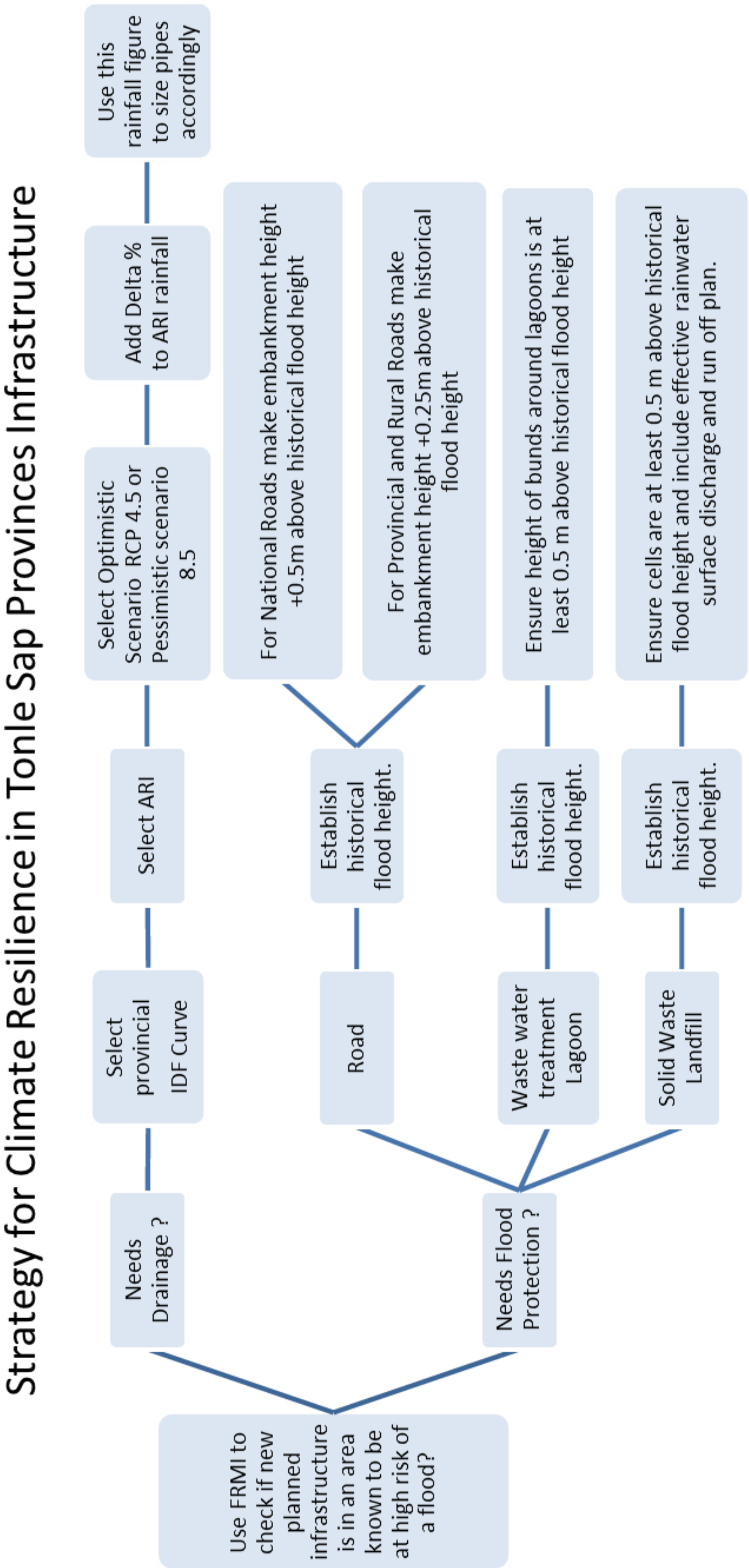


Figure 22-11　Flow Chart for Strategy of Climate Resilient Infrastructure around Tonle Sap

23. CONCLUSIONS

274. The Tonle Sap Basin has an Urban Development Framework which guides sustainable growth and climate resilient infrastructure development.

275. There are many policy initiatives on Climate Change in Cambodia. Climate Change Action Plans have been prepared for many ministries and sectors.

276. There are at least four separate recent climate change projections for the Tonle Sap area. Not all projections contain the same parameters but a comparison can be made.

Table 23-1 Comparison of Climate Change Projections from Various Sources

Parameter	Season	USAID 2013	MOWRAM 2014	Battambang 2015	Pursat extrapolated from Battambang	Average
Rainfall	Wet Season	+8%	+4%	+8%	+7.5%	+6.9%
	Dry Season	+1-2mm		-2.5%	-4%	-3.25%
Temperature	Wet Season	+3.2ºC	+1.7ºC	+2.6ºC	+3.5ºC	+2.5ºC
	Dry Season	+2.6ºC		+1.9ºC		+1.75ºC
Floods	Wet Season	No change	+9%			+9%
Drought	Dry Season	+15 days	+6 days			+10.5 days

277. From the above it can be seen that wet season rainfall may increase by 7%, dry season rainfall may drop -3%, wet season temperatures may increase by +2.5ºC and dry season temperatures by +1.75ºC. Flood occurrences and duration may increase by 9% and dry spells increase by 10 days. These projections are for the year 2050 under the A1B scenario which approximates to RCP6.0.

278. Uncertainty is a major consideration. There are at least three different and contrary factors to consider:

- more rain in the Tonle Sap basin due to climate change
- more flow in the Mekong river due to upstream earlier snow melt
- less flow in the Mekong river due to upstream hydro dams

All of these add to uncertainty in choosing parameters for design.

279. The MPWT software FRMI gives flood risks. It is targeted at road segments but it does cover the whole of Cambodia. The projections given in the FRMI software are based on current conditions and future values for 2055 under a high CO_2 climate change scenario which is RCP 8.5. They are a “broad brush” approach and one value can relate to upwards of 10kms of road. However they do cover the whole of Cambodia and despite limitations on their accuracy are considered useful.

280. The NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) were developed in support of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5). The NEX-GDDP dataset includes RCP 4.5 and RCP 8.5 and

gives daily maximum temperature, minimum temperature, and precipitation for the periods from 1950 through 2100. The data covers the entire earth at a resolution of 0.25 degrees (~25 km x 25 km) and has been used in this report.

281. Some projections have been made for RCP6.0 and some for RCP8.5. The projections indicate that when extending out to 2050 and beyond there is not much difference between results for RCP 6.0 and RCP 8.5.

282. The main conclusions on precipitation are:

- Annual rainfall may remain unchanged but rainfall will increase more in the wettest months by being of stronger duration. This will lead to longer dry periods. There may be "mini-droughts" during the wet season.
- Precipitation will increase most in the south-west and decrease in the north-east.
- Both the maximum 5-day and 1-day storms are expected to increase. The projected increases are 10% for 2030, 20% for 2050 and 30% or more for 2070.
- The relative increase in rainfall is heavier for short durations.

283. If hourly or short term data on rainfall is lacking daily rainfall figures can be used to estimate hourly rainfall for drainage design calculations. In general, the one hourly rainfall figure is 20-40% of daily although figures of 60% have been recorded around Phnom Penh. When in doubt a higher figure should be used.

284. Based on actual short term rainfall measurements there is significant variation across the country with some provinces experiencing almost twice the short term intensity of other provinces.

285. Data for Kampong Thom indicate 50mm per hour. Data for Banthey Meanchey indicate over 90mm per hour. The former figure (50mm/hr) is typical of a heavy downpour and the latter figure (90mm/hr) signifies extremely heavy rain.

286. Extremely heavy rain is usually the descriptor for rainfall of 200mm / day or higher. If 90mm is falling in one hour then the factor of 50% applies, that is to say it is very plausible that 50% of a daily rainfall occurs in one hour. This is supported by the measured data from Pochentong Airport.

287. It is recommended that if daily rainfall is known then a figure of 50% of the daily rainfall be taken as the peak hourly rainfall. This is conservative.

288. There is a pronounced difference in historical and projects IDFs around Tonle Sap. IDFs have been given for each province. These should be used in design.

289. For a common design event say a 1 in 10 year storm in the future under RCP4.5 which is an optimistic scenario, for :

- Kampong Chhnang; precipitation will remain the same
- Pursat: precipitation will go down by 6%
- Battambang; precipitation will go down by 26%
- Serei Sisophon; precipitation will go up by 26%
- Siem Reap; precipitation will go down by 34%
- Kampong Thom; precipitation will go up by 15%

290. Also for an extreme event say a 1 in 100 year storm in the future under RCP4.5 which is an optimistic scenario, for :

- Kampong Chhnang; precipitation will go down by 4%
- Pursat; precipitation will go down by 10%
- Battambang; precipitation will go down by 29%
- Serei Sisophon; precipitation will go up by 25%
- Siem Reap; precipitation will go down by 41%
- Kampong Thom; precipitation will go up by 19%

291. The correction factors for RCP8.5 are different as this is a pessimistic scenario.

292. For a common design event say a 1 in 10 year storm in the future under RCP8.5 for :

- Kampong Chhnang; precipitation will go up by 17%
- Pursat: precipitation will go up by 26%
- Battambang; precipitation will go up by 8%
- Serei Sisophon; precipitation will go up by 10%
- Siem Reap; precipitation will go up by 8%
- Kampong Thom; precipitation will go up by 28%

293. Also for an extreme event say a 1 in 100 year storm in the future under RCP8.5 which is an pessimistic scenario, for :

- Kampong Chhnang; precipitation will go up by 16%
- Pursat; precipitation will go up by 34%
- Battambang; precipitation will go up by 12%
- Serei Sisophon; precipitation will go up by 12%
- Siem Reap; precipitation will go up by 11%
- Kampong Thom; precipitation will go up by 32%

294. As this is a pessimistic scenario increases in short term precipitation can be expected. All sites will experience an increase in short storm intensity, by a maximum of 34%.

295. This factor should be applied to the IDF curves in detailed design. The full range of IDF curves for all provinces is given in the annexes.

296. The total cost of climate change adaptation measures in TLS2 are $3,185,000 out of a total project cost of US$82.2 million or 3.8%.

297. The total cost of climate change adaptation measures in TLS1 are still under review.

298. A flow chart for implementation of the Climate Resilience Strategy is given. (Figure 22-11) This strategy was delivered to the Provincial Government representatives in a workshop and well received.

24. ANNEX 1 TOR

24.1. Scope of Climate Change Adaptation in Urban Development

The overall objective of the consulting services is to strengthen resilience to climate change in the urban sector within and around the Tonle Sap Basin. Assistance will be provided to the six Tonle Sap provinces—Pursat, Kampong Chhnang, Kampong Thom, Banteay Meanchey, Siem Reap and Battambang, and to the Municipal Board of Governors of Pursat and Kampong Chhnang. Key objectives of the assistance are:

- *To develop a strategic plan for climate change adaptation in the urban development sector in and in the Tonle Sap Basin.*
- *To quantify potential climate change impacts in all urban areas in the Tonle Sap Basin and to identify appropriate planning and design measures to address these impacts (as requested by the six provincial governments around the Tonle Sap).*
- To revise building codes within all six Tonle Sap provinces to include latrine construction and standards, amongst others.
- To encourage effective debate on climate change adaptation.
- To ensure additional climate change measures are incorporated into the design of infrastructure interventions and community awareness programs, household sanitation and small-scale developments.

The scope of the consulting services involves three main components: (i) provision of technical assistance to assist government prepare a strategic plan for climate change adaptation in the urban sector in and around the Tonle Sap; (ii) quantification of potential climate change impacts and identification of measures to address these impacts; (iii) capacity development and training to incorporate climate change adaptation and disaster risk reduction management aspects into the national building code, and (iv) to provide knowledge for an effective debate on climate change issues and resilience. One package is proposed for the consulting services.

24.2. Key tasks

Key tasks are:

- Assist in the development of the strategic plan for climate change adaptation focusing on the urban sector in the provinces in and around the Tonle Sap.
- Undertake a targeted analysis of tangible impacts of climate change in urban areas of the Tonle Sap Basin.
- Identify and quantify the potential effects of climate change on key towns in Tonle Sap Basin and assess the impact on the design of infrastructure to address these.
- Review the sustainability and capacity of current engineering designs, standards and guidelines in use by the various ministries involved in planning and infrastructure provision in view of climate change.
- Provide a comprehensive guide to the incorporation of climate change measures into spatial planning and the planning and design of infrastructure in the urban areas.
- Link the work to other ongoing initiatives including the national programme under the National Adaptation Programme of Action to climate change (NAPA), the Clean Cities programme, and projects supported by development partners, including work under the ADB TA for Mainstreaming Climate Change Resilience into Development Planning in Cambodia.
- Review the National Building Code and those in use with all Tonle Sap provinces, and propose measures for the inclusion of climate change adaptation.
- Draft regulations for latrine construction and appropriate standards.

- Incorporation of the above regulations into the building codes of the six Tonle Sap provinces.
- Assist in the preparation of climate resilient community actions plans in Kampong Chhnang and Pursat.
- Establish and populate data base on good practices on climate change adaptation and building resilience.
- Conduct a series of workshops on climate change adaptation for key stakeholders.
- Ensure coordination and provide information (and feedback) to the PMIS consultant team to ensure additional climate change measures are incorporated into the design of infrastructure interventions and community awareness programs, household sanitation and small-scale developments.

25. ANNEX 2 BUILDING CODE AND SANITATION

25.1. Climate Resilient Buildings

25.1.1. Wooden House

Figure 25-1 Wooden house on stilts

Foundation: Brick or concrete foundation under posts or stilts

Walls: Local hard wood

Roofs: Tile, thin sheets, or grass leaves tied with nails or wire ropes

25.1.2. Metal Sheet House

Figure 25-2 Metal sheet house on stilts

Foundation: Brick, rock, or concrete foundation (RCC Fabricated and RCC Cast-In-Situ)

Walls: Corrugated galvanized iron (CGI) sheets supported by wooden frames

Roofs: Thin CGI sheets fixing with nails

Figure 25-3 Metal sheet house on ground

25.1.3. Causes of Damage to Houses in Floods

The impact of floods to housing is due to several reasons: a) Flood depth, b) Flood duration, c) Uplift due to soil saturation and d) Horizontal force created by flood waves or currents. Direct flood hazard is associated with other types of secondary hazards such as storms, lightning, slope instability, ground settlement, etc. Floodwater can submerge buildings and cause various degrees of damage from staining of walls to structural collapse depending on flood depth and/ or duration and type of building.

25.1.4. Effects of Flood on Different Parts of House

Foundation: The uplift forces that can lift up a house are due to the displacement of water. These uplift forces may be the result of the actual building materials (the floating nature of the wood products, or due to air on the interior of a tightly built structure. When the forces associated with the flood exceed the weight of the building components and the connections to the foundation system, the structure may float from its foundation.

Rapidly flowing water may scour the soils that support the foundation. As the soils are eroded from around and below a foundation system, the capacity of the foundation is reduced. Ultimately this may lead to a shifting of the building, a partial collapse of the structural system, or even a complete collapse of the structure.

Wall: Water flowing around the building during a flood event generates loads on the structure.

These loads are the frontal impact loads from the upstream flow, the drag on the sides of the building, and the suction on the rear face of the building as the floodwaters flow around the structure. High velocity current creates lateral pressures that may be capable of collapsing structural walls or floor systems. The magnitude of the loads is dependent upon the floodwater velocity and the shape of the structure.

Roof: Generally, floods do not affect a roof unless the house is submerged. In such condition, if also accompanied by strong current, roof materials can get detached and washed away.

25.1.5. Causes of Damage to Houses in Typhoons

The impact of typhoons to housing is caused from several reasons: a) Wind pressure, b) Windborne debris, c) Flood resulted from heavy rain and 4) Storm surge.

Strong wind pressure may cause roof uplift and wall/roof suction. High wind speed resulted from typhoon cause windborne debris impacting the houses which may damage the housing exteriors.

25.1.6. Effects of Typhoon on Different Parts of House

Foundation: Foundations are rarely damaged by high wind speed due to typhoon. They are generally damaged by secondary effects of typhoon such as flood and storm surge.

Wall: High wind pressure around a house during a typhoon generates suction to the house that may blow out the house. Wind can go inside the house through insecure windows and doors, the high pressure inside can blow out the house. Strong wind speed is another major concern during typhoon due to windborne debris. Windborne missiles (i.e. trees, benches, etc.) outside a house can damage the exterior, including roof covering, windows, doors, and other openings. Moreover, windborne debris leads to create high pressure inside the house due to the wind go inside the house and then blow out the house if the missiles damage the house.

Roof: High wind pressure around a house during a typhoon generates suction force to a roof.

The suction force may damage the house by lifting its roof. In such condition, building contents are also damaged by raining. Windborne debris can damage a roof and then generate similar damage to the wall.

25.1.7. Houses on Stilts

The traditional wooden houses on stilts, with regional and ethnic design variations, are most common in rural Cambodia. Stilt houses are houses raised on piles over the surface of the soil or a body of water. They are built primarily as a protection against flooding, but also serve to keep out insects or nuisance animals, especially those that threaten human society by spreading diseases or destroying crops and livestock. The shady space under the house can be used for work or storage. Primarily regarded for its protection from flooding, there are many additional advantages to the stilt house. It is relatively easy to construct, and the design makes use of land that might be otherwise unsuitable for housing. The house type considers safety (cyclone and flood proof structure) and sustainability (environmentally-friendly), and social responsibility (considering social and cultural preferences). It incorporates the construction of autonomous and appropriate houses built with locally available materials and can be easily extended.

Figure 25-4 Wooden House Climate Proofed on stilts

25.1.8. Vulnerable Part of a House

For the foundation it is recommended to use prefab concrete stilts. For added protection it is very wise to pour a lean concrete into the excavation holes before placing the prefab stilts into them. Concrete will give it the extra support needed particularly against flooding. Sawn timber of common sizes is used as posts, beams, joists, bracings, rafters, purlins, floor boards, wall cladding, valance, and barge boards. Many local hardwood species are resistant to termite/pest attack. Assembling is done with conventional timber joints. Structural frame is bolted, cladding and floors are nailed.

1. Foundation / footing
2. Anchoring of wooden stilts to RCC footing
3. Joint detail of joist corner and center
4. Fixing rafter to wall plate
5. Eave detail
6. Face detail
7. Ridge detail

Figure 25-5 Vulnerable parts of a house

The ground under the house needs to be strong enough to support the building, even if it is flooded or is exposed to earthquakes. A proper assessment of the underground area and removal of overlying earth of poor quality are essential in all cases. The quality and lifespan of a house depend to a great extent on how the foundations are made. Poor foundations can ultimately lead to damage and deterioration that is difficult to repair. Wherever possible reinforced pre-fab footings should be selected.

The connection between RC footing and the wooden column is of utmost importance to resist wind forces. If properly connected the footings act not only as load bearing elements but also as “weights” to hold the house structure down in cases of cyclones. In common house construction of rural Cambodia a solid joint is often missing. As a result, houses are blown off by cyclones.

25.2. Sanitation

25.2.1. Characteristics of Sanitation

Recurrent floods, cyclone and prolonged water logging make it hard to adapt appropriate sanitation for those who are living with flood and water logging conditions. Every year a large area of Cambodia is inundated due to annual flood and this is common and normal phenomenon.

Furthermore, a huge number of sanitation facilities are damaged or destroyed due to natural disaster like flood and cyclone. There is a huge demand for flood resistant, appropriate, socially and culturally accepted technological options for safe disposal of human excreta in the flood prone areas. However, there are limited technological options for sanitation for flood prone areas.

Sanitation facilities face the following typical problems during flooding and cyclones :

- The faecal material contained in the latrine pit will be widely distributed during flooding, resulting in wide-spread contamination with pathogens, including wells for a long time even after the flood event
- The sanitation facilities cannot be used during flood, and may even get destroyed during the flood event, in situations where the water level is very high and strong currents occur
- Cabins might be destroyed by strong winds

The minimal requirements of sanitation facilities are ;

- Technologies and structure and their application should be such that it does not contaminate the environment; and the use of sanitation service prevents disease transmission
- Sanitation services should be affordable for all, socially acceptable and do not compromise the dignity of the users, women, in particular
- Technologies and structure are durable and their repair and maintenance are within the reach of the households
- Target should be one latrine for each household; to achieve this target appropriate technology should be developed

25.2.2. Appropriate Latrines for rural Cambodia

The following options are appropriate :

- Single Ventilated Pit Latrine
- Raised Pit Latrine
- Single Pit for Pour Flush Latrine
- Water Sealed Pit Latrine
- Septic tank

25.2.3. Single Ventilated Pit Latrine

The Single VIP is a Ventilated, Improved Pit. It is an improvement over the Single Pit because continuous airflow through the ventilation pipe vents odors and acts as a trap for flies as they escape towards the light.

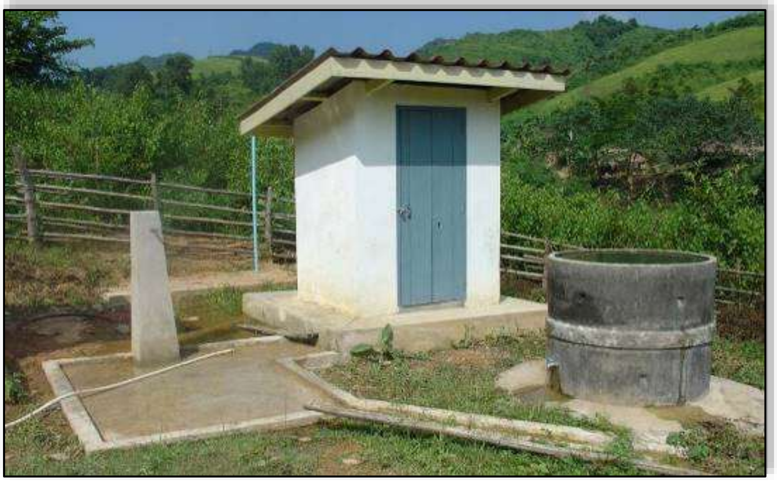


Figure 25-6 Front view with stand pipe of single ventilated pit latrine

To keep the Single VIP free of flies and odors, regular cleaning and maintenance is required. Dead flies, spider webs, dust and other debris should be removed from the ventilation screen to ensure a good flow of air.

Positive aspects are :

+ Flies and odors are significantly reduced (compared to non-ventilated pits)
+ Does not require a constant source of water
+ Can be built and re-paired with locally available materials
+ Can be used immediately after construction
+ Low (but variable) capital costs depending on materials and pit depth
+ Small land area required

Negative aspects are :

- Sludge requires secondary treatment and/or appropriate discharge
- Costs to empty may be significant compared to capital costs
- Low reduction in BOD and pathogens

25.2.4. Raised Pit Latrine

The Raised Pit Latrine is designed for zones with regular floods and water log areas. It is constructed in the same way as Single VIP’s.

Figure 25-7 Front view of raised pit latrine

Maintenance is similar to a Single Pit Latrine

Positive aspects are :

+ Functions at all times (before, during and after flood)
+ Easy desludging
+ Smooth function
+ Highly recommended in flood and cyclone prone areas
+ Plinth is not vulnerable to heavy rain
+ Flies and odors are significantly reduced (compared to non-ventilated pits)
+ Does not require a constant source of water
+ Can be built and re-paired with locally available materials
+ Can be used immediately after construction
+ Low (but variable) capital costs depending on materials and pit depth
+ Small land area required

Negative aspects are :

- Sludge requires secondary treatment and/or appropriate discharge
- Costs to empty may be significant compared to capital costs

25.2.5. Single Pit for Pour Flush Latrine

This technology consists of single pit connected to a Pour Flush Toilet. The water in the toilet bowl is connected to a discharge pipe slope 30% to the chamber. The blackwater is collected in the pits and allowed to slowly infiltrate into the surrounding soil. With time, the solids are sufficiently dewatered and can be manually removed with a shovel.

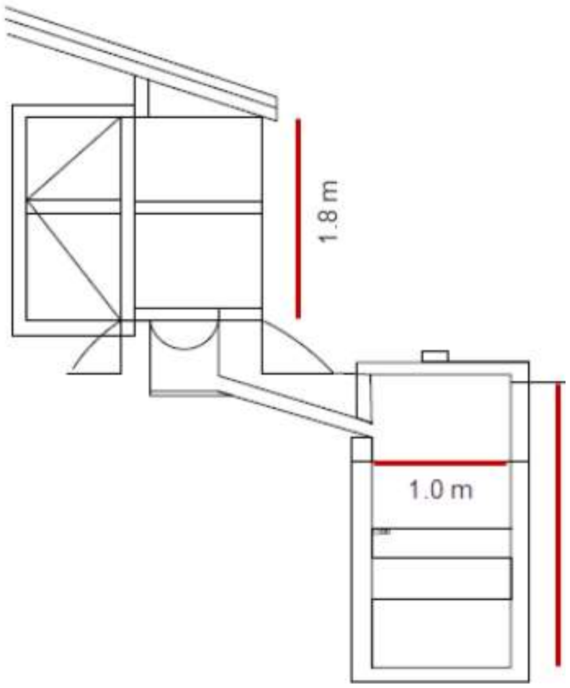


Figure 25-8 Single Pit for Pour Flush Latrine

The pits must be emptied regularly. After a recommended two-year resting time, the pits should be emptied manually using long handled shovels. If the pits are self-emptied there are no operational costs except for any re-placements to the structure or pit in the event of damage.

Positive aspects are :

+ Can be built and repaired with locally available materials
+ Excavation of humus is easier than faecal sludge
+ Flies and odors are significantly reduced (compared to pits without a waterseal)
+ Low capital costs depending on materials; no or low operating costs if self-emptied
+ Moderate reduction in pathogens
+ Can allow for sanitization and composting prior to emptying and reuse in agriculture

Negative aspects are :

- Excreta requires manual removal
- Water container inside to be filled with water

25.2.6. Water Sealed Pit Latrine

This is the seated toilet and consists of single pit under a Pour Flush Toilet. The water in the toilet bowl is directly connected to the chamber. The blackwater is collected in the pits and allowed to slowly infiltrate into the surrounding soil. With time, the solids are sufficiently dewatered and can be manually removed with a shovel.

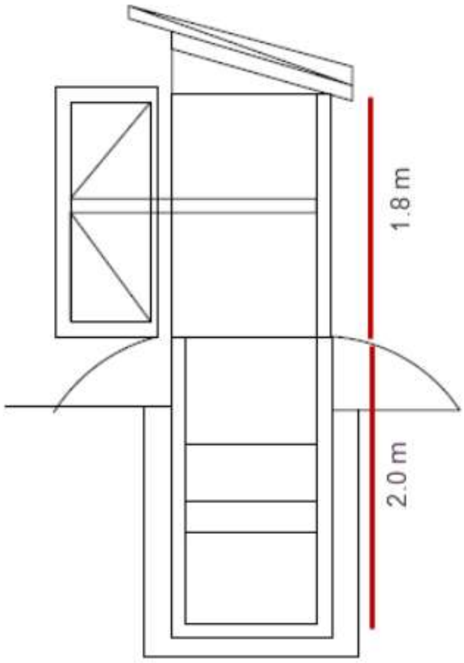


Figure 25-9 Vertical section of water sealed pit latrine

The pits must be emptied regularly. After a recommended two-year resting time, the pits should be emptied manually using long handled shovels. If the pits are self-emptied there are no operational costs except for any re-placements to the structure or pit in the event of damage.

Positive aspects are :

+ Can be built and repaired with locally available materials
+ Can be built with local skilled people
+ Cab be comfortable and low cost for people in rural area
+ Can be suitable to the climate and environment in rural area

Negative aspects are :

- Excreta require manual removal
- Water can inside to be filled with water

25.2.7. Septic Tank

A Septic Tank is a water-tight chamber made of concrete, fiberglass, PVC or plastic, for the storage and treatment of blackwater and greywater. Settling and anaerobic processes reduce solids and organics, but the treatment is only moderate.

Septic Tanks should be checked to ensure that they are watertight and the levels of the scum and sludge should be monitored to ensure that the tank is functioning well. Because of the delicate ecology, care should be taken not to discharge harsh chemicals into the Septic Tank. The sludge must be removed periodically.

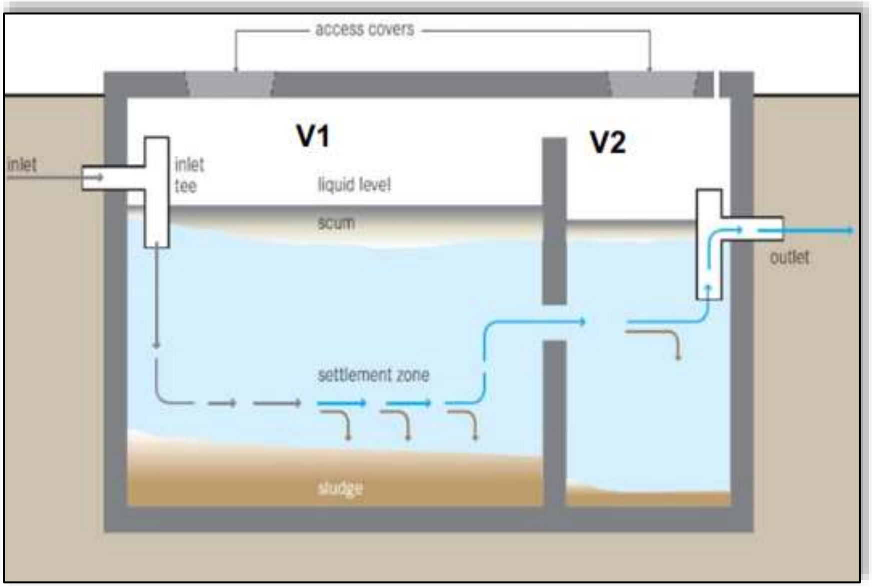


Figure 25-10 Double Chamber Septic Tank

Positive aspects are :

+ Can be built and repaired with locally avail-able materials
+ Long service life
+ No real problems with flies or odors if used correctly
+ Low capital costs, moderate operating costs
+ Small land area required

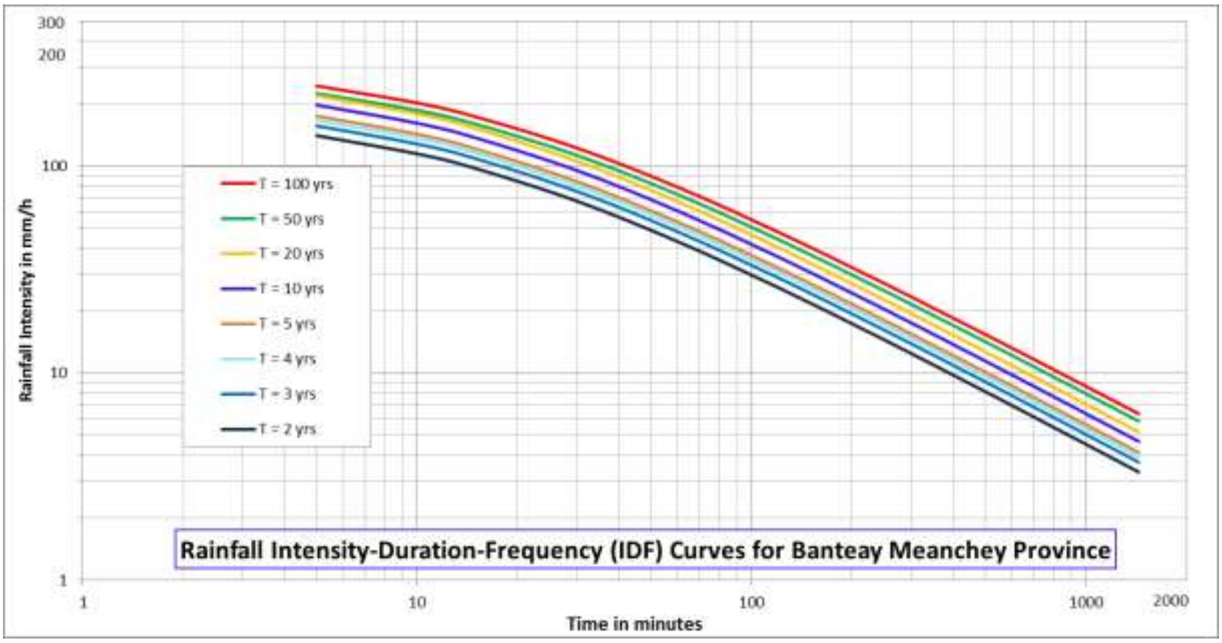
Negative aspects are :

- Low reduction in pathogens, solids and organics
- Effluent and sludge require secondary treatment and/or appropriate discharge
- Requires constant source of water

26. ANNEX 3 IDF CURVES FOR ALL PROVINCES IN CAMBODIA WHERE MOWRAM KEEP RECORDS

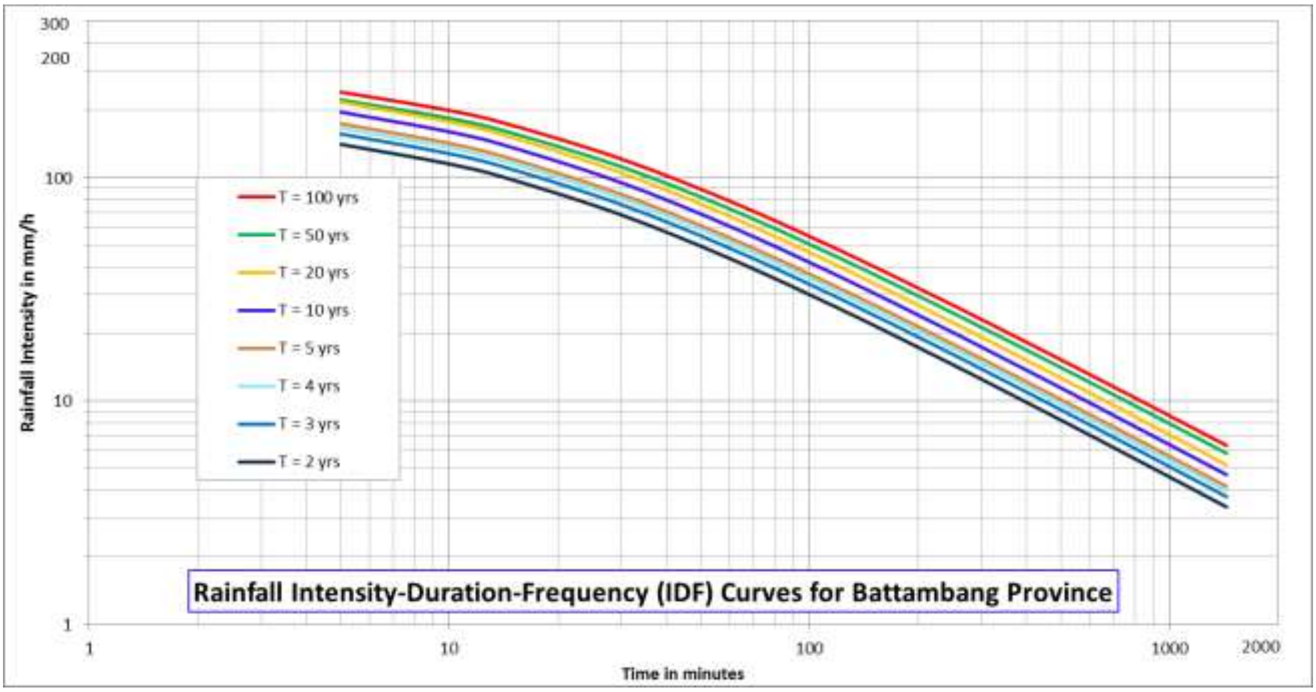
26.1. Rainfall Intensity-Duration-Frequency (IDF) Curves for Banteay Meanchey Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	140	156	167	174	197	219	225	224	243
10	min	114	128	136	142	161	178	184	185	201
15	min	97	108	115	121	136	151	156	159	172
30	min	67.7	75	80	84	95	106	109	113	122
1	h	43.2	48.2	51.4	53.7	61	67	70	73	79
2	h	25.9	28.9	30.8	32.2	36.4	40.4	41.7	44.2	48.0
4	h	14.9	16.7	17.8	18.6	21.0	23.3	24.0	25.8	28.0
8	h	8.4	9.4	10.0	10.5	11.8	13.1	13.6	14.7	15.9
12	h	6.0	6.7	7.1	7.5	8.4	9.4	9.6	10.5	11.4
18	h	4.3	4.7	5.1	5.3	6.0	6.6	6.8	7.5	8.1
24	h	3.3	3.7	4.0	4.1	4.7	5.2	5.4	5.9	6.4



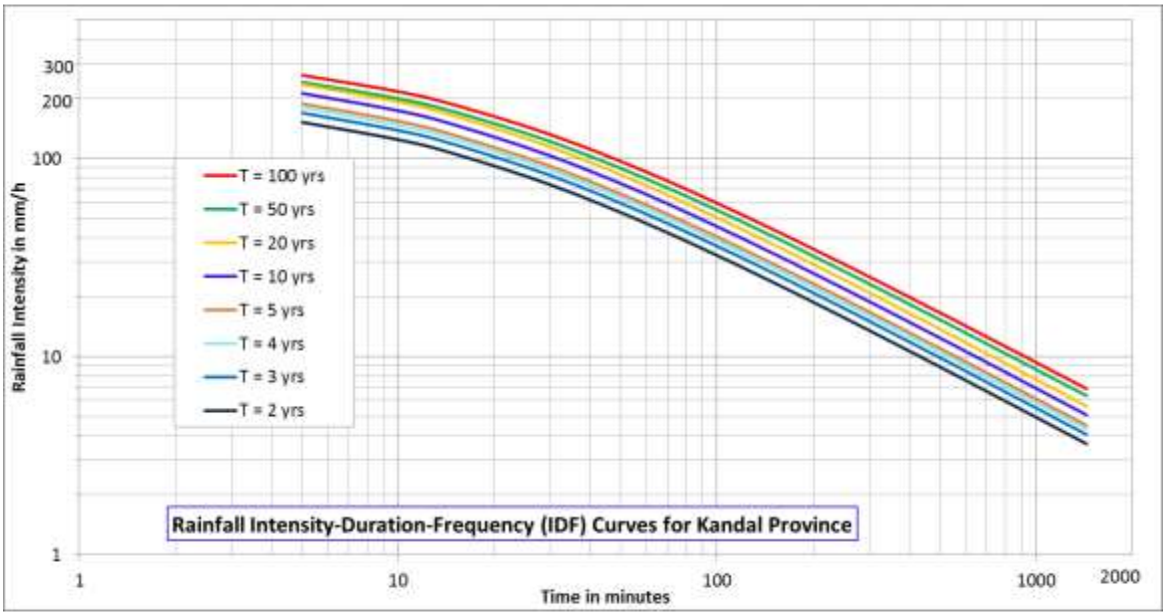
26.2. Rainfall Intensity-Duration-Frequency (IDF) Curves for Battambang Province

Duration		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	141	157	167	175	197	218	225	223	242
10	min	115	128	136	143	161	178	183	185	200
15	min	98	109	116	121	136	151	156	158	171
30	min	68.2	76	81	84	95	105	109	112	121
1	h	43.6	48.4	51.6	53.9	61	67	69	73	79
2	h	26.1	29.0	30.9	32.3	36.4	40.3	41.6	44.0	47.7
4	h	15.1	16.7	17.8	18.6	21.0	23.2	24.0	25.6	27.8
8	h	8.5	9.4	10.1	10.5	11.8	13.1	13.5	14.6	15.8
12	h	6.0	6.7	7.2	7.5	8.4	9.3	9.6	10.4	11.3
18	h	4.3	4.8	5.1	5.3	6.0	6.6	6.8	7.4	8.1
24	h	3.4	3.7	4.0	4.2	4.7	5.2	5.3	5.8	6.3



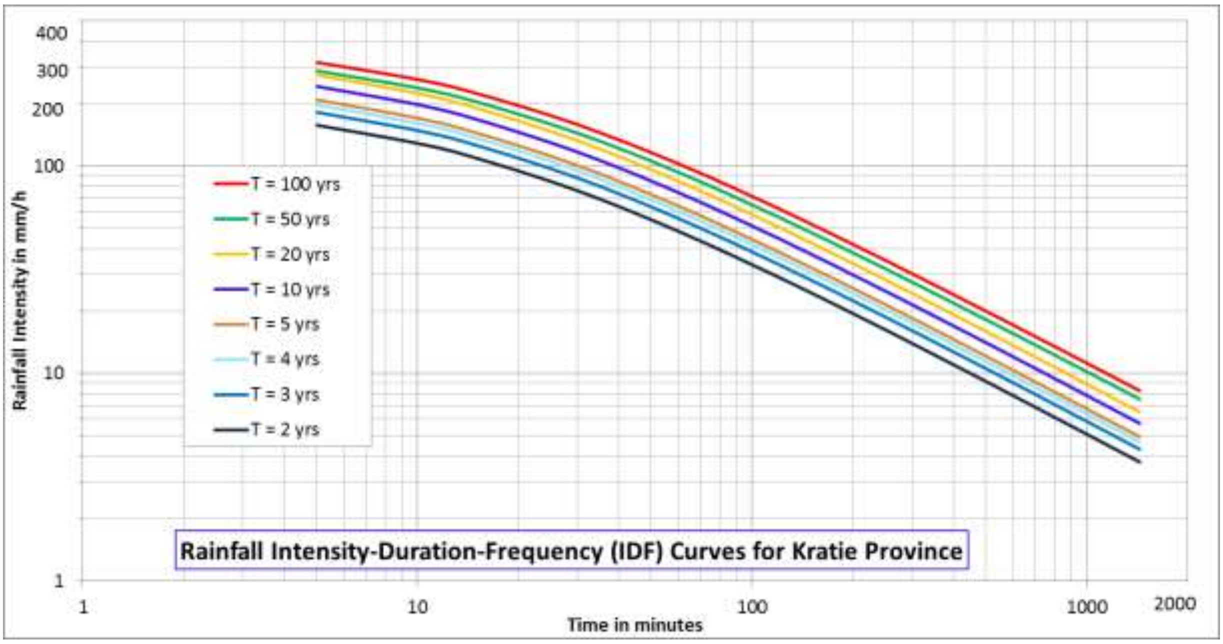
26.3. Rainfall Intensity-Duration-Frequency (IDF) Curves for Kandal Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	153	170	181	189	214	237	244	243	264
10	min	125	139	148	155	175	194	200	201	218
15	min	106	118	126	131	148	164	169	172	187
30	min	73.8	82	88	92	103	115	118	122	132
1	h	47.1	52.5	55.9	58.4	66	73	75	79	86
2	h	28.2	31.5	33.5	35.0	39.5	43.8	45.2	47.9	52.0
4	h	16.3	18.1	19.3	20.2	22.8	25.3	26.1	27.9	30.3
8	h	9.2	10.2	10.9	11.4	12.9	14.3	14.7	15.9	17.2
12	h	6.5	7.3	7.8	8.1	9.1	10.1	10.5	11.4	12.3
18	h	4.6	5.2	5.5	5.8	6.5	7.2	7.4	8.1	8.8
24	h	3.6	4.0	4.3	4.5	5.1	5.6	5.8	6.4	6.9



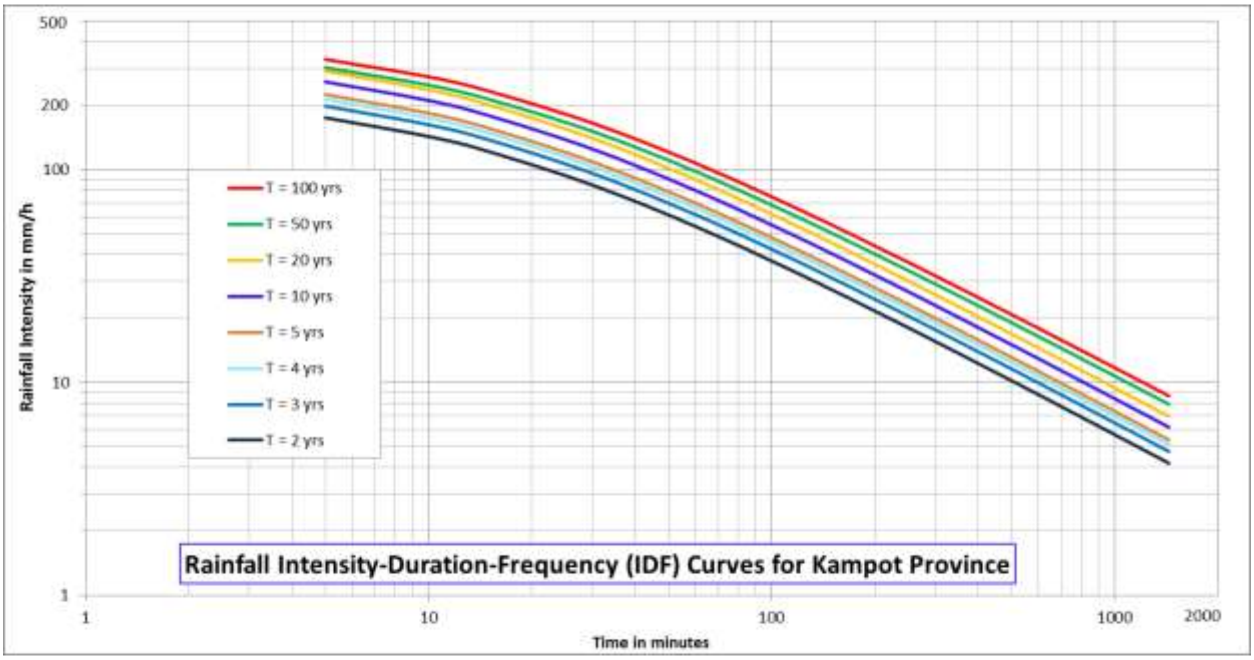
26.4. Rainfall Intensity-Duration-Frequency (IDF) Curves for Kratie Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	157	181	197	208	242	274	284	287	316
10	min	128	148	161	170	197	224	232	238	261
15	min	109	126	136	144	168	190	197	203	224
30	min	76.0	88	95	101	117	132	137	144	158
1	h	48.5	55.9	60.7	64.2	75	85	88	93	103
2	h	29.1	33.5	36.4	38.5	44.7	50.7	52.6	56.6	62.3
4	h	16.8	19.3	21.0	22.2	25.8	29.2	30.3	33.0	36.3
8	h	9.5	10.9	11.8	12.5	14.5	16.5	17.1	18.8	20.6
12	h	6.7	7.8	8.4	8.9	10.3	11.7	12.2	13.4	14.7
18	h	4.8	5.5	6.0	6.3	7.3	8.3	8.6	9.6	10.5
24	h	3.7	4.3	4.7	4.9	5.7	6.5	6.8	7.5	8.3



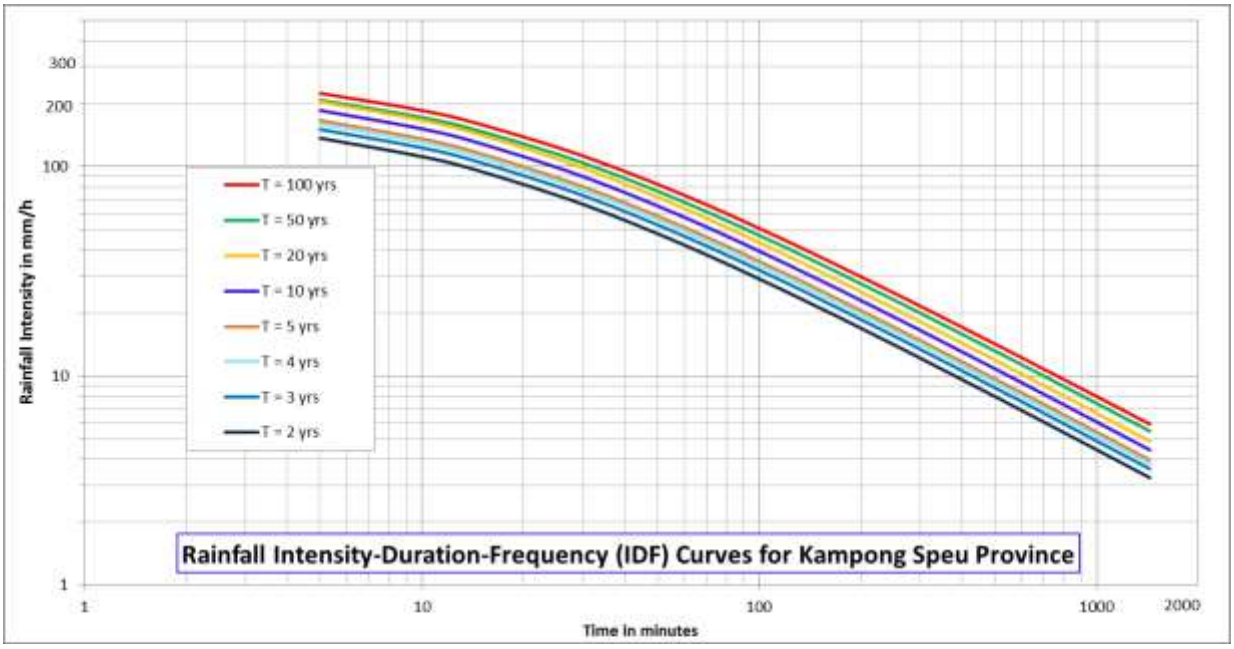
26.5. Rainfall Intensity-Duration-Frequency (IDF) Curves for Kampot Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	176	200	215	226	260	292	302	303	331
10	min	144	163	176	185	212	238	246	250	274
15	min	122	138	149	157	180	202	209	215	235
30	min	85.0	97	104	109	125	141	146	152	166
1	H	54.3	61.6	66.3	69.8	80	90	93	98	108
2	H	32.5	36.9	39.8	41.8	48.0	53.9	55.8	59.7	65.3
4	H	18.8	21.3	22.9	24.1	27.7	31.1	32.2	34.8	38.0
8	H	10.6	12.0	12.9	13.6	15.6	17.5	18.2	19.8	21.6
12	H	7.5	8.5	9.2	9.7	11.1	12.5	12.9	14.1	15.5
18	H	5.3	6.1	6.5	6.9	7.9	8.9	9.2	10.1	11.0
24	H	4.2	4.7	5.1	5.4	6.2	6.9	7.2	7.9	8.7



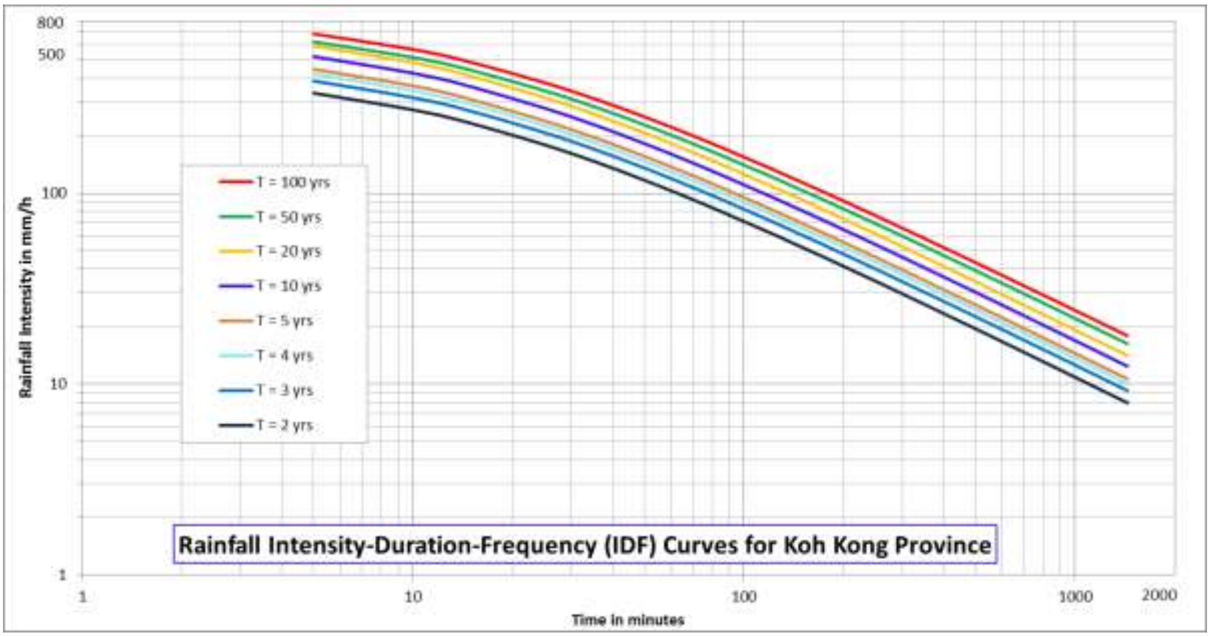
26.6. Rainfall Intensity-Duration-Frequency (IDF) Curves for Kampong Speu Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	137	151	160	166	186	205	211	208	225
10	min	112	123	131	136	152	167	172	172	186
15	min	95	105	111	115	129	142	146	147	159
30	min	66.2	73	77	80	90	99	102	104	113
1	h	42.3	46.6	49.3	51.4	57	63	65	68	73
2	h	25.3	27.9	29.6	30.8	34.4	37.9	39.0	41.1	44.3
4	h	14.6	16.1	17.0	17.8	19.8	21.8	22.5	23.9	25.8
8	h	8.2	9.1	9.6	10.0	11.2	12.3	12.7	13.6	14.7
12	h	5.9	6.5	6.8	7.1	8.0	8.8	9.0	9.7	10.5
18	h	4.2	4.6	4.9	5.1	5.6	6.2	6.4	6.9	7.5
24	h	3.3	3.6	3.8	4.0	4.4	4.9	5.0	5.4	5.9



26.7. Rainfall Intensity-Duration-Frequency (IDF) Curves for Koh Kong Province

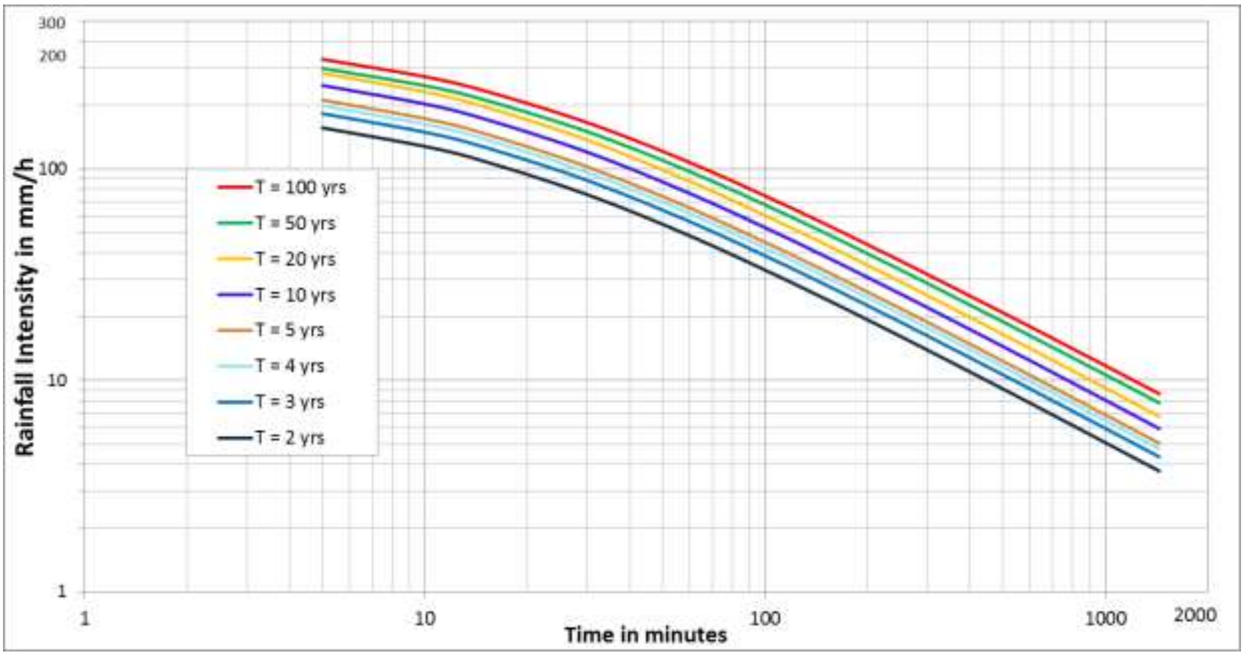
Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	335	388	422	447	521	592	615	622	685
10	min	273	317	344	365	425	483	502	515	566
15	min	232	269	292	310	361	410	426	441	485
30	min	161.8	187	204	216	252	286	297	312	344
1	h	103.3	119.7	130.1	137.9	161	183	190	202	223
2	h	61.9	71.7	78.0	82.7	96.4	109.5	113.7	122.7	135.1
4	h	35.7	41.4	45.0	47.7	55.6	63.1	65.6	71.5	78.7
8	h	20.2	23.3	25.4	26.9	31.3	35.6	37.0	40.7	44.8
12	h	14.3	16.6	18.1	19.1	22.3	25.3	26.3	29.1	32.0
18	h	10.2	11.8	12.8	13.6	15.8	18.0	18.7	20.7	22.8
24	h	8.0	9.2	10.0	10.6	12.4	14.1	14.6	16.3	17.9



Rainfall Intensity-Duration-Frequency (IDF) Curves for Koh Kong Province

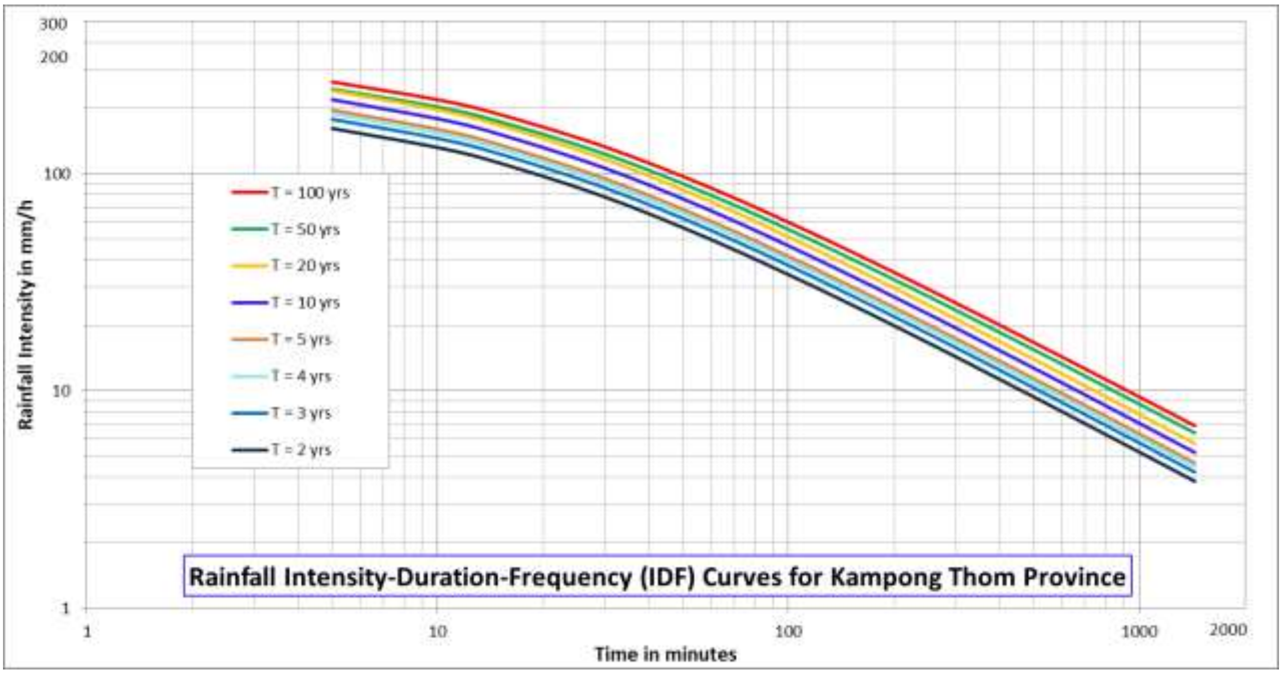
26.8. Rainfall Intensity-Duration-Frequency (IDF) Curves for Kampong Chhnang Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	157	183	200	212	249	284	295	299	330
10	min	128	149	163	173	203	232	241	248	273
15	min	109	127	138	147	172	197	204	212	234
30	min	75.7	88	96	102	120	137	142	150	166
1	h	48.3	56.4	61.6	65.4	77	88	91	97	107
2	h	29.0	33.8	36.9	39.2	46.0	52.5	54.5	59.0	65.2
4	h	16.7	19.5	21.3	22.6	26.5	30.3	31.4	34.4	38.0
8	h	9.4	11.0	12.0	12.8	15.0	17.1	17.7	19.6	21.6
12	h	6.7	7.8	8.5	9.1	10.6	12.1	12.6	14.0	15.4
18	h	4.8	5.5	6.1	6.4	7.5	8.6	9.0	10.0	11.0
24	h	3.7	4.3	4.7	5.0	5.9	6.7	7.0	7.8	8.6



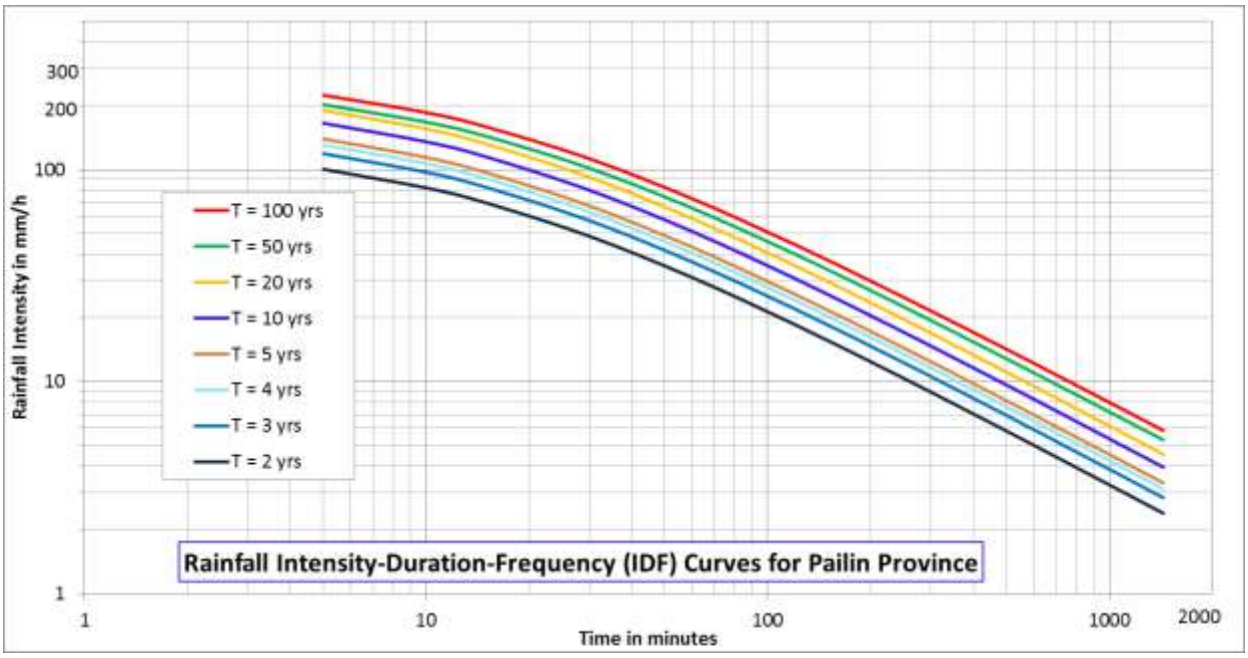
26.9. Rainfall Intensity-Duration-Frequency (IDF) Curves for Kampong Thom Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	161	178	188	196	219	241	248	245	264
10	min	132	145	154	160	179	197	202	202	219
15	min	112	123	130	136	152	167	172	173	187
30	min	78.0	86	91	95	106	116	120	123	133
1	h	49.8	54.8	58.1	60.5	68	74	76	80	86
2	h	29.8	32.9	34.8	36.2	40.5	44.5	45.8	48.3	52.1
4	h	17.2	19.0	20.1	20.9	23.3	25.7	26.4	28.1	30.4
8	h	9.7	10.7	11.3	11.8	13.2	14.5	14.9	16.0	17.3
12	h	6.9	7.6	8.1	8.4	9.4	10.3	10.6	11.4	12.3
18	h	4.9	5.4	5.7	5.9	6.6	7.3	7.5	8.1	8.8
24	h	3.8	4.2	4.5	4.7	5.2	5.7	5.9	6.4	6.9



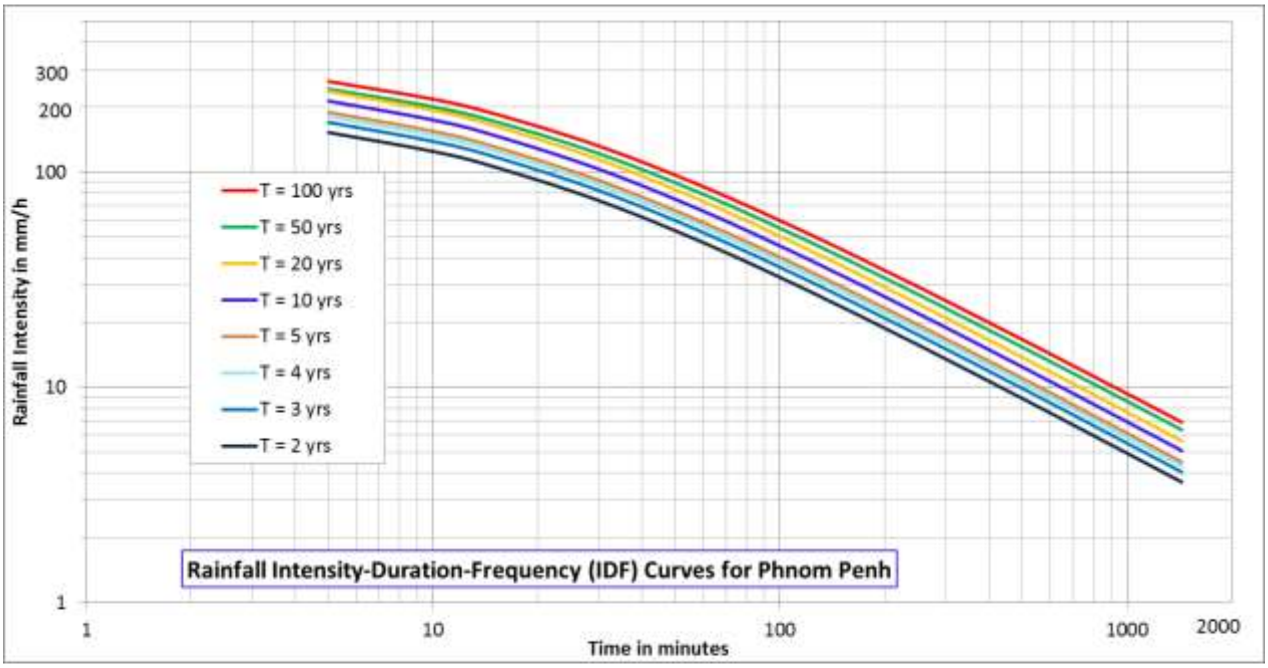
26.10. Rainfall Intensity-Duration-Frequency (IDF) Curves for Pailin Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	100	119	131	140	166	191	199	203	225
10	min	82	97	107	114	135	156	162	168	186
15	min	70	82	91	97	115	132	138	144	159
30	min	48.5	58	63	68	80	92	96	102	113
1	h	31.0	36.7	40.4	43.1	51	59	61	66	73
2	h	18.6	22.0	24.2	25.8	30.6	35.3	36.7	40.0	44.3
4	h	10.7	12.7	14.0	14.9	17.7	20.3	21.2	23.3	25.8
8	h	6.0	7.2	7.9	8.4	10.0	11.5	11.9	13.2	14.7
12	h	4.3	5.1	5.6	6.0	7.1	8.2	8.5	9.5	10.5
18	h	3.0	3.6	4.0	4.2	5.0	5.8	6.0	6.7	7.5
24	h	2.4	2.8	3.1	3.3	3.9	4.5	4.7	5.3	5.9



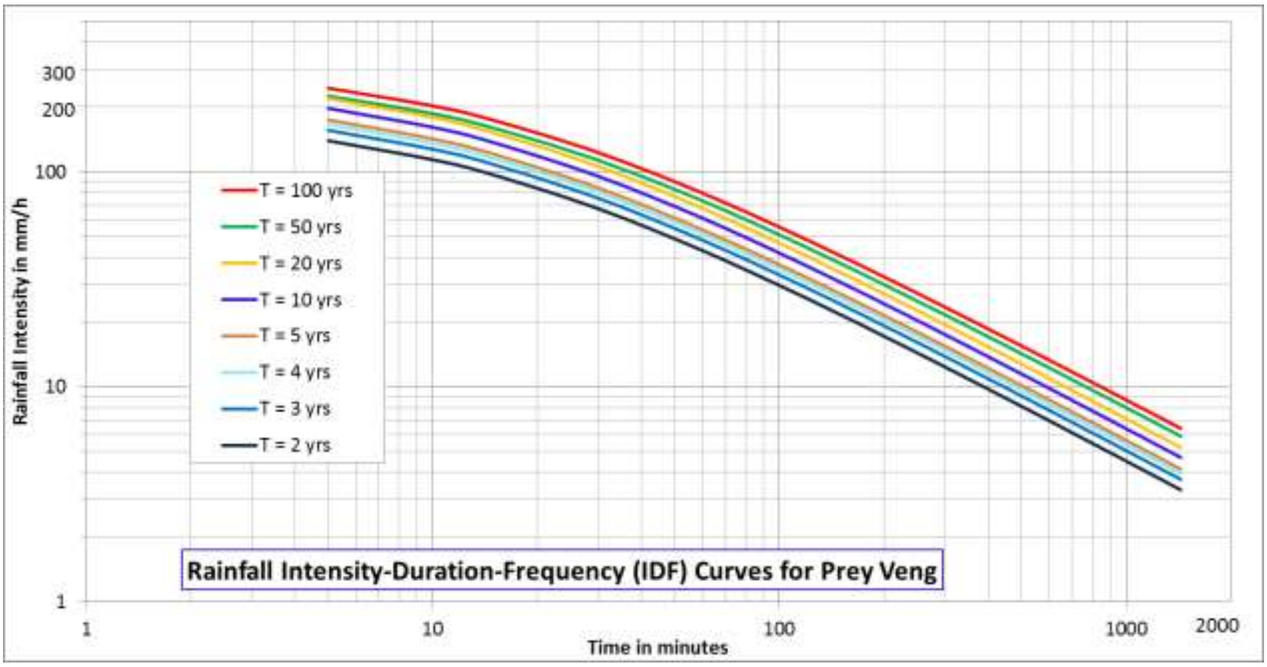
26.11. Rainfall Intensity-Duration-Frequency (IDF) Curves for Phnom Penh

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	153	170	181	189	214	237	244	243	264
10	min	125	139	148	155	175	194	200	201	218
15	min	106	118	126	131	148	164	169	172	187
30	min	73.8	82	88	92	103	115	118	122	132
1	h	47.1	52.5	55.9	58.4	66	73	75	79	86
2	h	28.2	31.5	33.5	35.0	39.5	43.8	45.2	47.9	52.0
4	h	16.3	18.1	19.3	20.2	22.8	25.3	26.1	27.9	30.3
8	h	9.2	10.2	10.9	11.4	12.9	14.3	14.7	15.9	17.2
12	h	6.5	7.3	7.8	8.1	9.1	10.1	10.5	11.4	12.3
18	h	4.6	5.2	5.5	5.8	6.5	7.2	7.4	8.1	8.8
24	h	3.6	4.0	4.3	4.5	5.1	5.6	5.8	6.4	6.9



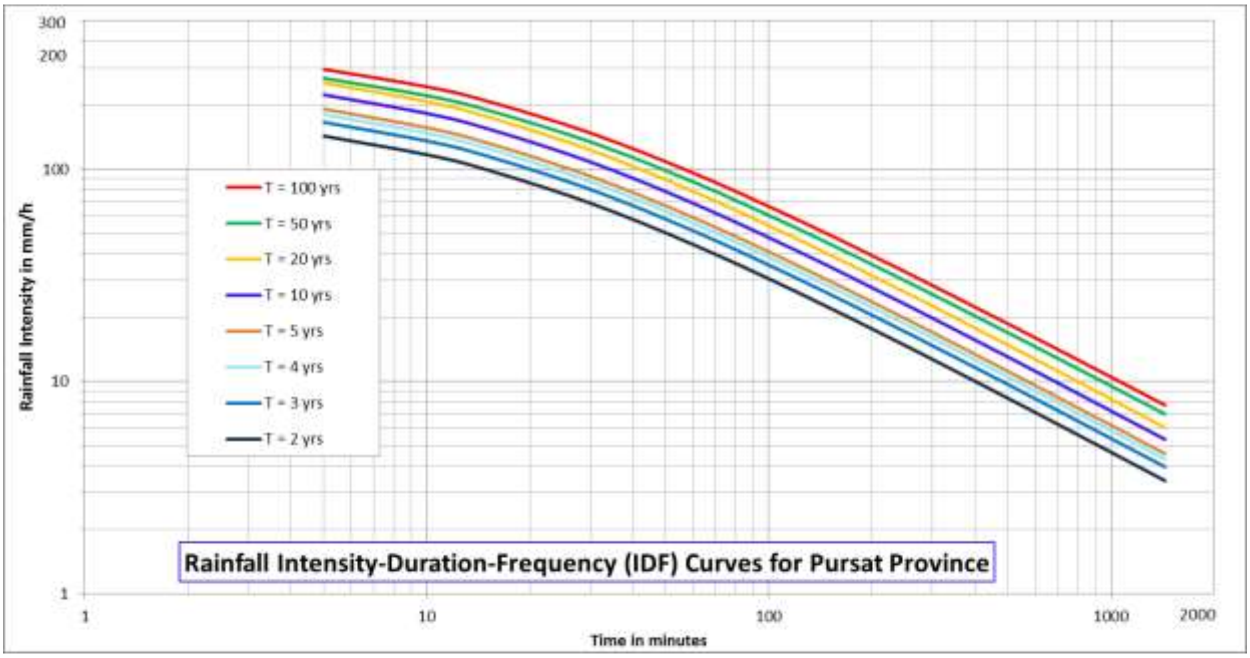
26.12. Rainfall Intensity-Duration-Frequency (IDF) Curves for Prey Veng Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	139	156	166	174	197	219	226	225	245
10	min	114	127	136	142	161	179	185	186	203
15	min	97	108	115	121	137	152	157	160	173
30	min	67.4	75	80	84	95	106	109	113	123
1	h	43.0	48.1	51.3	53.8	61	68	70	73	80
2	h	25.8	28.8	30.8	32.2	36.5	40.6	41.9	44.5	48.3
4	h	14.9	16.6	17.7	18.6	21.0	23.4	24.1	25.9	28.1
8	h	8.4	9.4	10.0	10.5	11.9	13.2	13.6	14.7	16.0
12	h	6.0	6.7	7.1	7.5	8.4	9.4	9.7	10.5	11.4
18	h	4.2	4.7	5.1	5.3	6.0	6.7	6.9	7.5	8.2
24	h	3.3	3.7	4.0	4.1	4.7	5.2	5.4	5.9	6.4



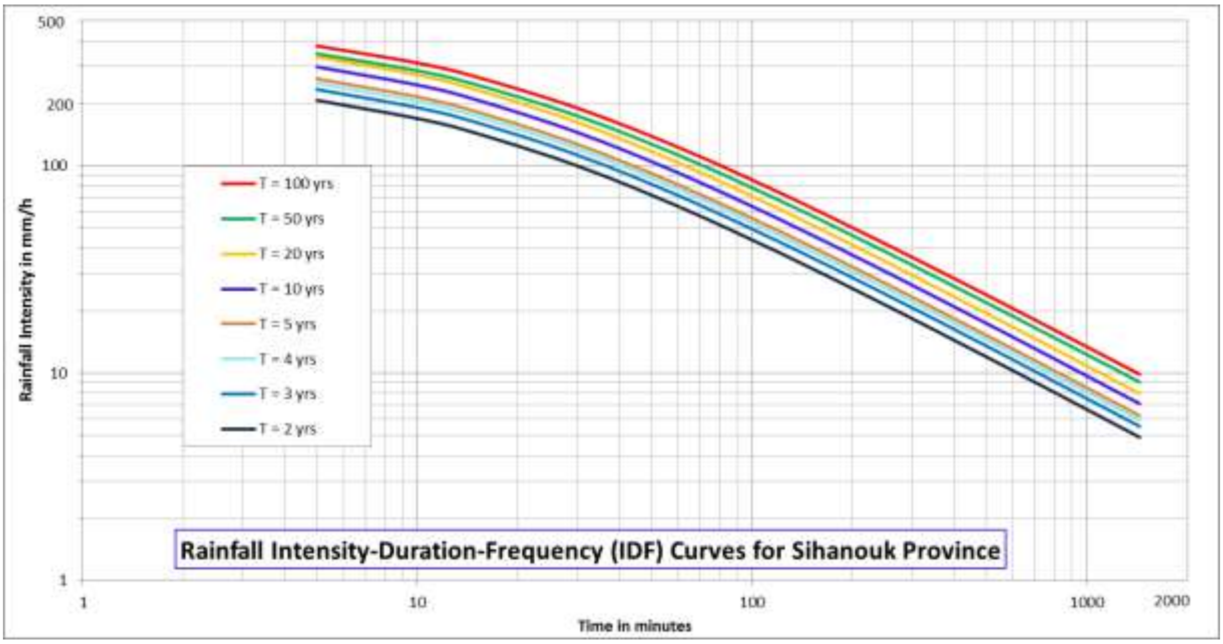
26.13. Rainfall Intensity-Duration-Frequency (IDF) Curves for Pursat Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	143	166	181	192	224	255	265	268	295
10	min	117	136	148	157	183	208	216	222	244
15	min	99	115	125	133	155	177	183	190	209
30	min	69.2	80	87	93	108	123	128	135	148
1	h	44.2	51.3	55.8	59.2	69	79	82	87	96
2	h	26.5	30.7	33.5	35.5	41.4	47.2	49.0	52.9	58.3
4	h	15.3	17.7	19.3	20.5	23.9	27.2	28.2	30.8	33.9
8	h	8.6	10.0	10.9	11.5	13.5	15.3	15.9	17.5	19.3
12	h	6.1	7.1	7.7	8.2	9.6	10.9	11.3	12.5	13.8
18	h	4.3	5.0	5.5	5.8	6.8	7.7	8.0	8.9	9.8
24	h	3.4	4.0	4.3	4.6	5.3	6.1	6.3	7.0	7.7



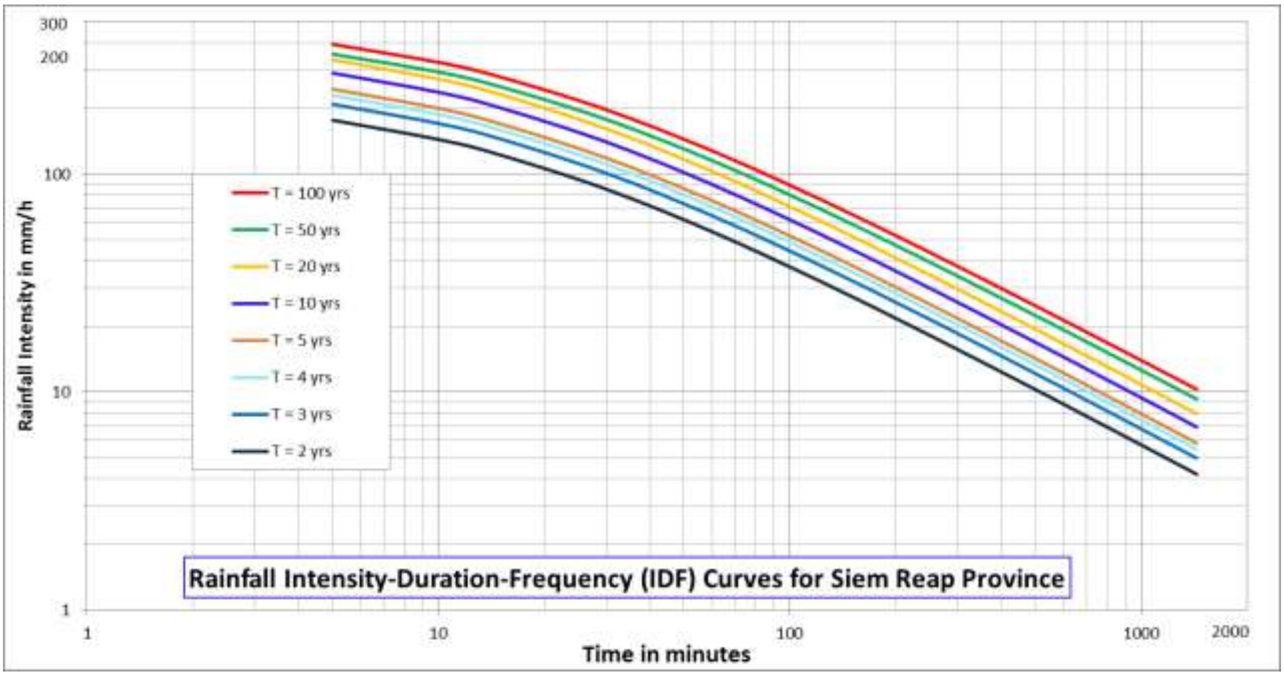
26.14. Rainfall Intensity-Duration-Frequency (IDF) Curves for Sihanouk Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	207	233	250	263	300	335	346	346	378
10	min	169	190	204	214	245	274	283	287	312
15	min	143	161	173	182	208	232	240	245	268
30	min	99.8	113	121	127	145	162	167	174	190
1	h	63.7	71.9	77.1	81.0	92	103	107	113	123
2	h	38.2	43.1	46.2	48.5	55.4	62.0	64.0	68.3	74.5
4	h	22.0	24.9	26.7	28.0	31.9	35.7	36.9	39.8	43.4
8	h	12.4	14.0	15.0	15.8	18.0	20.2	20.8	22.6	24.7
12	h	8.8	10.0	10.7	11.2	12.8	14.3	14.8	16.2	17.6
18	h	6.3	7.1	7.6	8.0	9.1	10.2	10.5	11.5	12.6
24	h	4.9	5.5	5.9	6.2	7.1	8.0	8.2	9.1	9.9



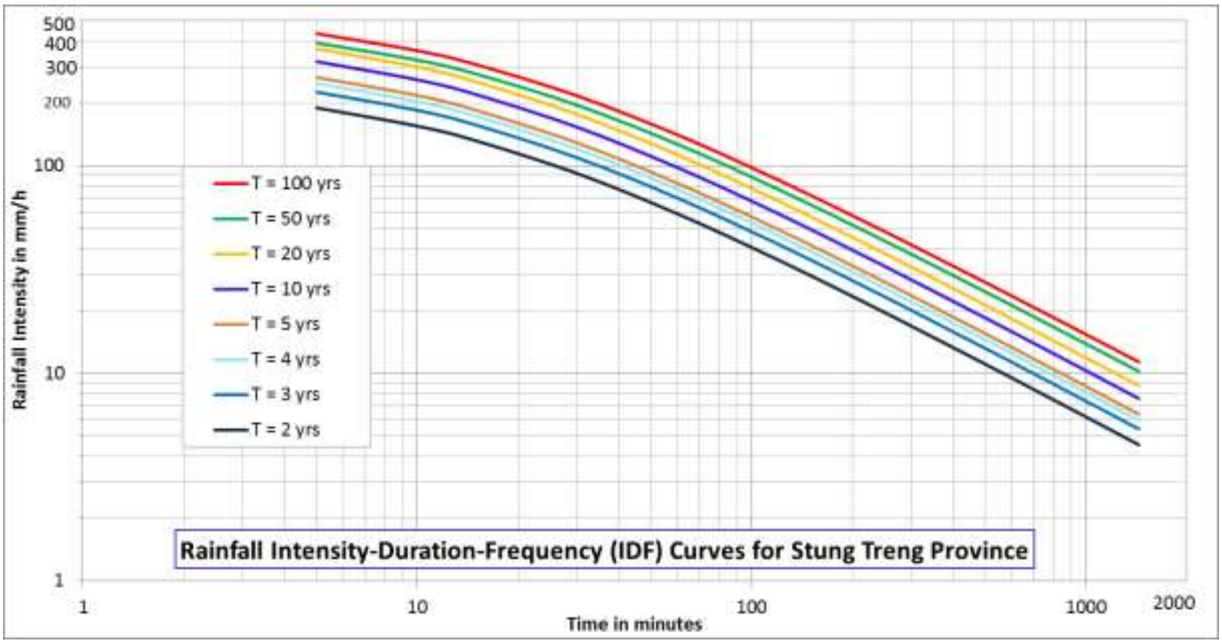
26.15. Rainfall Intensity-Duration-Frequency (IDF) Curves for Siem Reap Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	177	209	230	245	291	334	348	355	394
10	min	144	171	188	200	237	273	284	294	326
15	min	122	145	159	170	201	232	241	252	279
30	min	85.3	101	111	118	140	162	168	178	198
1	h	54.5	64.5	70.9	75.7	90	103	107	115	128
2	h	32.7	38.7	42.5	45.4	53.8	61.8	64.4	70.1	77.7
4	h	18.8	22.3	24.5	26.2	31.0	35.6	37.1	40.8	45.2
8	h	10.6	12.6	13.8	14.8	17.5	20.1	20.9	23.2	25.7
12	h	7.6	8.9	9.8	10.5	12.4	14.3	14.9	16.6	18.4
18	h	5.4	6.3	7.0	7.4	8.8	10.1	10.6	11.8	13.1
24	h	4.2	5.0	5.5	5.8	6.9	7.9	8.3	9.3	10.3



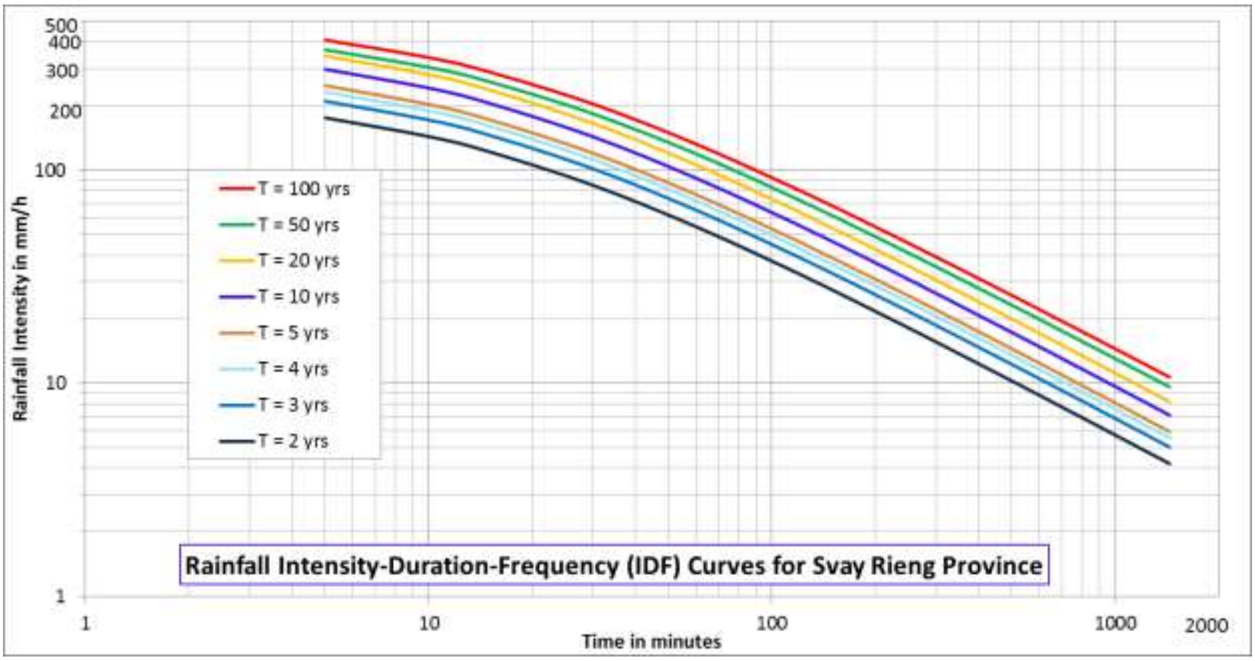
26.16. Rainfall Intensity-Duration-Frequency (IDF) Curves for Stung Treng Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	191	227	250	268	318	367	383	391	434
10	min	156	185	204	218	260	300	312	324	359
15	min	132	157	173	185	221	254	265	277	308
30	min	92.1	110	121	129	154	177	185	196	218
1	h	58.8	70.0	77.2	82.5	98	113	118	127	141
2	h	35.3	42.0	46.3	49.5	58.9	67.9	70.8	77.2	85.7
4	h	20.3	24.2	26.7	28.5	34.0	39.2	40.8	45.0	49.9
8	h	11.5	13.7	15.1	16.1	19.2	22.1	23.0	25.6	28.4
12	h	8.2	9.7	10.7	11.4	13.6	15.7	16.4	18.3	20.3
18	h	5.8	6.9	7.6	8.1	9.7	11.1	11.6	13.0	14.5
24	h	4.5	5.4	5.9	6.4	7.6	8.7	9.1	10.2	11.4



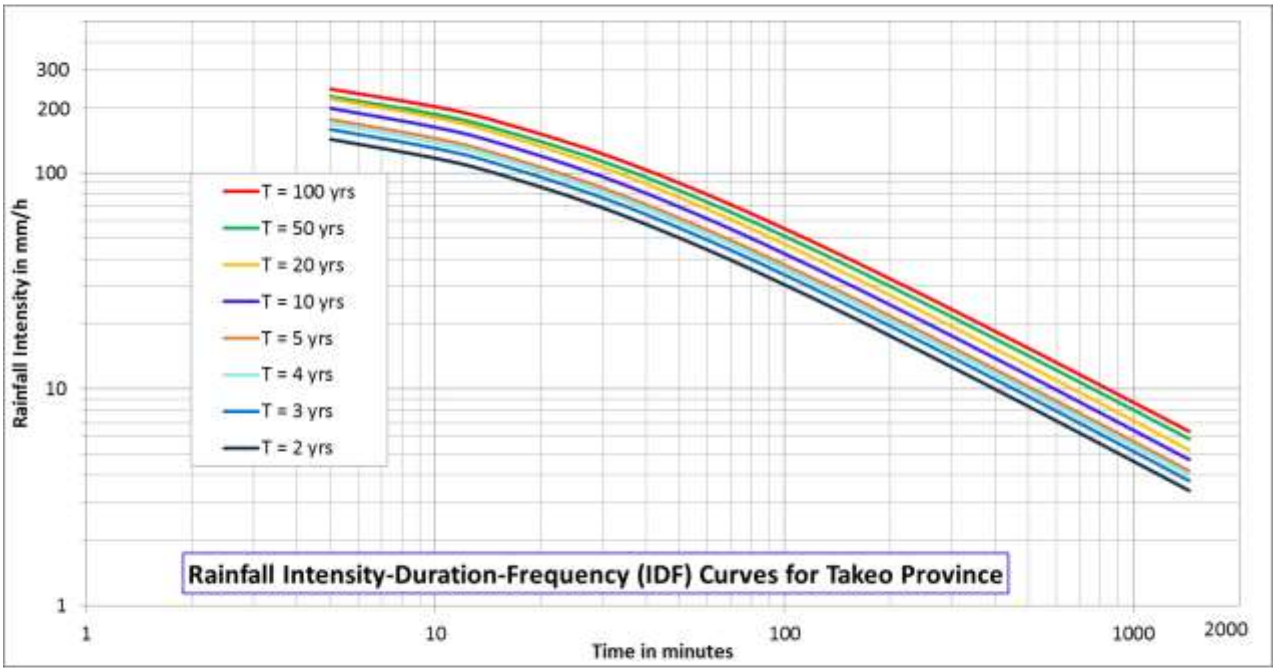
26.17. Rainfall Intensity-Duration-Frequency (IDF) Curves for Svay Rieng Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	176	211	233	250	298	344	359	368	409
10	min	144	172	190	204	243	281	293	304	338
15	min	122	146	162	173	206	239	249	261	290
30	min	85.2	102	113	121	144	166	174	185	205
1	h	54.4	65.1	71.9	77.0	92	106	111	120	133
2	h	32.6	39.0	43.1	46.1	55.1	63.7	66.4	72.6	80.6
4	h	18.8	22.5	24.9	26.6	31.8	36.7	38.3	42.3	47.0
8	h	10.6	12.7	14.0	15.0	17.9	20.7	21.6	24.0	26.7
12	h	7.5	9.0	10.0	10.7	12.8	14.7	15.4	17.2	19.1
18	h	5.4	6.4	7.1	7.6	9.0	10.5	10.9	12.2	13.6
24	h	4.2	5.0	5.5	5.9	7.1	8.2	8.5	9.6	10.7



26.18. Rainfall Intensity-Duration-Frequency (IDF) Curves for Takeo Province

Duration t		Intensity-Duration-Frequency (mm/hrs)								
		Return Period, T								
		2	3	4	5	10	20	25	50	100
5	min	143	159	169	177	199	220	227	225	244
10	min	117	130	138	144	162	180	185	186	202
15	min	99	110	117	122	138	153	157	160	173
30	min	69.1	77	82	85	96	106	110	113	122
1	h	44.1	49.0	52.1	54.5	61	68	70	73	79
2	h	26.4	29.4	31.3	32.6	36.8	40.7	42.0	44.4	48.1
4	h	15.2	16.9	18.0	18.8	21.2	23.5	24.2	25.9	28.0
8	h	8.6	9.6	10.2	10.6	12.0	13.2	13.6	14.7	16.0
12	h	6.1	6.8	7.2	7.6	8.5	9.4	9.7	10.5	11.4
18	h	4.3	4.8	5.1	5.4	6.0	6.7	6.9	7.5	8.1
24	h	3.4	3.8	4.0	4.2	4.7	5.2	5.4	5.9	6.4



27. ANNEX 4 CLIMATE CHANGE ADAPTATION FOR TLS 1

27.1. Background

299. The Project is being implemented in the towns of Kampong Chhnang and Pursat in the Provinces of Kampong Chhnang and Pursat, respectively. The towns are about 100 km apart along the Tonle Sap Lake and Tonle Sap River, and connected by National Road No. 5. The Pursat Municipality is located in the southwest of Tonle Sap Lake, with the Stueng Pursat River draining to the Tonle Sap Lake. The Kampong Chhnang Municipality is located in the southeast of Tonle Sap Lake, with Kampong Chhnang and Pursat being some 90 km and 190 km from Phnom Penh respectively.

27.1.1. Kampong Chhnang

300. Kampong Chhnang is located about 80 km north of Phnom Penh on National Road No.5. It is situated at the southern end of the Tonle Sap basin, 35 km south of the main body of the lake. The town sits on the west bank of one of the main channels in the Tonle Sap river. Of the six main urban centres around the Tonle Sap, Kampong Chhnang is by far the closest to the lake itself.

301. The population of the Kampong Chhnang municipality in 2013 was estimated at 40,360. The municipality covers a large area and this figure includes a number of villages that are well outside the main urban area. The population of the contiguous urban area is estimated at 56,829 and a projected mid-growth rate of about 2.5% will give a population of about 86,000 by 2030.

27.1.2. Pursat Town

302. Pursat is located approximately 186km north of Phnom Penh on National Road No. 5. It is situated about 20km from the western edge of the Tonle Sap lake, on the banks of the Stueng Pursat river.

303. The estimated population of Pursat municipality in 2013 was 33,000. The population of the contiguous urban area is estimated at 49,044 and with a projected steady growth rate of about 2.5% if sustained would give about 75,000 urban dwellers in 2030.

27.1.3. Project Outcomes

304. The outcome of the project will be improved urban services and climate change resilience in Kampong Chhnang and Pursat municipalities. The project will enhance the urban environment, improve public health, and contribute to better quality, coverage and reliability of services for majority of residents as follows:

(i) The Project benefits 100,000 residents in Kampong Chhnang and Pursat
(ii) Pursat town center flooding reduced by 50%
(iii) Improved SWM in for some 19,600 households
(iv) Sanitation coverage achieved for 90% of households
(v) Institutional framework and adaptive capacities of USUs strengthened in climate resilience infrastructure, climate change and hygiene awareness.

27.2. Kampong Chhnang Designs

305. Kampong Chhnang municipality has stated that the annual flooding from the Tonle Sap River is a major obstacles to economic development. Improvement of environmental sanitation for the large communities living on and adjacent to Tonle Sap will alleviate difficulties caused by this annual event.

306. Kampong Chhnang urban area environmental improvements include

- Construction of a new controlled landfill site of 10ha at Phnom Tauch village with increased capacity
- Provision of equipment for solid waste collection
- Landfill management, including supervised closing of two open dumpsites in Kul Kuk village and Trork village.

307. This complements the Japan International Cooperation Agency's drainage project in the municipality and GIZ's support for development of an urban master plan.

27.3. Pursat Designs

308. Pursat Municipality urban area environmental improvements include :

- Construction of about 9.9 km of primary and secondary drains in the town center with associated road improvements and improved wastewater treatment
- Riverbank erosion protection in select locations along the Pursat River, including revetment and groins
- Development of a new controlled landfill of about 28 ha at Toul Mkak village (Roleap Sangkat, Pursat town) and associated access road of about 900 meters
- Provision of equipment for solid waste collection
- Landfill management, including equipment and closure of two old open dumpsites in Toul Mkak village (Roleap Sangkat, Pursat town) and Sras Srang village (Prey Gny Sangkat, Pursat town).

309. This complements ADB's previous support to the Dhamnak Chheukrom Irrigation System Rehabilitation (located about 40 km upstream). About 20% of the town's roads have drains connected to National Highway No. 5. Town drainage will improve the stormwater drainage system to accommodate more intense rainfall. The project will support increased economic activities in the town, and facilitate residents' continued access to social services.

310. The riverbank protection work will be carried out in three places : complementing the ongoing work near the Provincial Governor's Office ; and stabilizing embankment in two locations on the South bank upstream of the railway bridge.

27.3.1. Rainfall Intensity

311. Climate change studies have projected an increase in rainfall intensity during rainy days by 2055. A decrease in the total yearly rainfall that is projected for some locations is a result of a decrease in the number of rainy days not a reduction in intensity. The CSIRO's CCAM model projected an increase of daily rainfall of 10 to 20mm.

312. While climate models are run at intervals of 1 hour or less the outputs that are generated are at the scale of 1 day. Predictions of rainfall intensity in terms of mm per hour may under estimate maximum rainfall intensity. As a guide, in tropical conditions, hourly rain fall can be assumed to be 20-40% of daily rainfall.

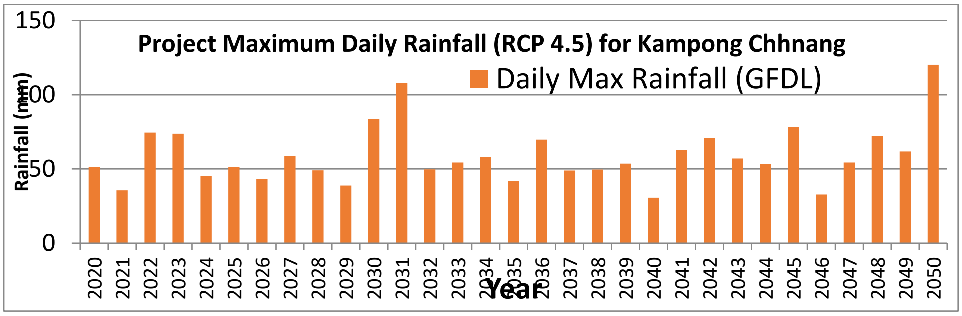


Figure 27-1 Project Maximum Daily Rainfall (RCP 4.5) for Kampong Chhnang

313. For Kampong Chhnang the sites are in locations that are classified as being at **Low to Moderate Risk** of flooding.

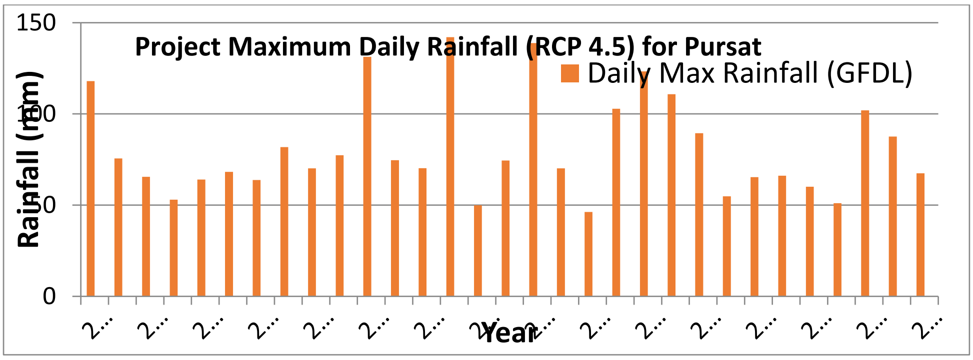


Figure 27-2 Project Maximum Daily Rainfall (RCP 4.5) for Pursat

314. For Pursat the sites are in locations that are classified as being at **Moderate to Very High Risk** of flooding.

27.3.2. Adaptation Measures

315. Adaptation to climate change in infrastructure design may require intervention at several stages. Some modifications can be introduced at preliminary design, other items will be required at detailed design phase.

Table 27-1 Climate Change Adaptation Measures

Civil Works

- Increased height of access road above flood levels
- Raise embankment boundaries
- Modification of side slope ratios to avoid soil loss in heavy rain

Hydrological Studies

- Coordination of data collection/recording systems e.g. rainfall, stream gauges
- Adjustment of design criteria to account for increased flows
- Allowances for effects of future dam and irrigation schemes.

Drainage Design

- Additional waterway opening at bridge sites
- Additional cross-culvert capacity
- Debris defectors and energy dissipaters

- Install Debris Deflectors
- Sub-drainage systems.
- Turf surfaces on side slopes.

Erosion Controls

- Side ditch linings in areas of high flow velocity
- Retaining walls and gabions to stabilize slopes
- Bioengineering of embankments

Operations and Maintenance

- Regular inspection and repair of drainage systems
- Regular cleaning of culverts and side ditches
- Regular cleaning of box and pipe culvert systems
- Cleaning of culverts before known storms or typhoons
- Quick restoration of items following major flood events.

27.3.3. Elevation

316. For access roads the crest level should be a minimum height of the water level of floods with a recurrence interval of 1 in 10 years plus 0.25 meters.

27.3.4. Flood Calculations

317. The commonly used Rational Method can only be applied to catchment areas less than $10km^2$. For larger areas the Generalised Tropical Flood Model (GTFM) developed by Fiddes and Watkins (1984) should be used.

27.3.5. Embankments

318. A layer of soil shall be constructed over the completed and trimmed side slopes of embankments. A complete dense cover of growing grass shall be established on the soil covering the side slopes. Where the side of an embankment is subject to wave action, a hedge of shrubs shall be established growing on a line 1.2 m in elevation below the top edge of the roadway.

27.3.6. Drainage Design

319. IDF curves must be used very cautiously in design. Error factors of 2 to 1 are common. However overestimating the anticipated rainfall will give a higher safety factor in the design of the drains.

27.3.7. Maintenance

320. The importance of maintenance cannot be over emphasized. No matter how good the design a lack of maintenance will render it ineffective. Bar screens should be installed on upstream inlets to pipes to catch floating debris. Vertical screens are easier to clean by manual labor.

321. Local communities can be hired for drain cleaning and grass cutting. This only needs unskilled labor and providing of some simple tools. The community sense of ownership can improve the efficiency of maintenance.

27.4. Incremental Climate Change Costs of TLS1

For large infrastructure such as the Kampong Chhnang flood protection embankment and the Pursat drainage, the changes in rain fall and temperature might affect some design criteria. For smaller infrastructure such as landfills, local conditions such as the conditions of drainage and other developments that may affect drainage are more important than an increase in rainfall and incremental cost because of climate change may be difficult to quantify.

These issues still need to be addressed by the detailed design consultants. No details on incremental costs have been provided yet.

28. ANNEX 5 CLIMATE CHANGE ADAPTATION FOR TLS 2

28.1. Background

322. The Second Integrated Urban Environmental Management in the Tonle Sap Basin Project (the project or TLS2) will support the Government of Cambodia in improving urban services and enhancing climate resilience in three of the towns in the Tonle Sap Basin. The location of the project is in the three secondary cities of Serei Saophoan, Banteay Meanchay Province, Battambang, Battambang Province and Stueng Saen, Kampong Thom Province. These provinces are three of the five provinces that surround the Tonle Sap lake basin.

323. The project is part of ADB's program in the Tonle Sap Basin and will build on an ongoing project, TLS1 under which similar improvements are being implemented in two other towns in the Tonle Sap basin, these being Pursat and Kampong Chhnang. Some of the aspect of TLS2 in Kampong Chhnang have been removed and allocated to TLS1 and so Kampong Chhnang no longer features in TLS 2.

324. The project focuses on improvement of wastewater treatment, storm water drainage and solid waste management. Sewage treatment will be through construction of sewage treatment plants (STPs) based on oxidation ponds also known as “lagoons” which are simple to construct and maintain. The piped sewerage system will also double up in places as a drainage system. Solid waste management will include improved collection and disposal at controlled landfills, although collection is not part of this project.

325. Serei Saophoan and Stueng Saen will each have three subprojects whereas Battambang will have two. The subprojects are ranked in terms of priority. A summary of the project interventions are shown in table 28-1 below.

Table 28-1 Summary of Project Interventions

City	Province	Sub-Project		
		Sewage Treatment Plant	Drainage	Landfill
Serei Saophoan	Banteay Meanchay	Priority 1	Priority 1	Priority 2
Stueng Saen	Kampong Thom	Priority 1	Priority 1	Priority 2
Battambang	Battambang	Priority 1	✖	Priority 2

326. The project locations are dominated by rice fields and other agricultural land which contains many surface water bodies including ponds, rivers discharging to the Tonle Sap lake and river, and a network of irrigation canals used for paddy field cultivation.

327. The most significant climate change risks associated with the sub-projects are during operation. Both STPs and landfill sites can be impacted by heavy rain and flooding. Increased temperatures and droughts can reduce potable water supplies which may directly impact the flows into the STPs. However if effectively managed, the new facilities will bring about improvements to the living conditions of the population of the project areas.

28.2. Impacts

328. The main impacts are:

- Annual rainfall may remain unchanged but rainfall will increase more in the wettest months by being of stronger duration. This will lead to longer dry periods. There may be “mini-droughts” during the wet season.
- Precipitation will increase most in the south-west and decrease in the north-east.
- Both the maximum 5-day and 1-day storms are expected to increase. The projected increases are 10% for 2030, 20% for 2050 and 30% or more for 2070.
- The relative increase in rainfall is heavier for short durations.
- An increase of 20% on existing IDF curves will allow for a global temperature increase of 2^{o}C. This factor is conservative and is recommended as a design factor.

329. If hourly or short term data on rainfall is lacking daily rainfall figures can be used to estimate hourly rainfall for drainage design calculations. In general, the one hourly rainfall figure is 20-40% of daily although figures of 60% have been recorded around Phnom Penh. When in doubt a higher figure should be used.

330. Climate change will cause an increase in short term intense rainfall. An increase of 20% on existing rainfall intensity should be allowed for future events.

331. The MPWT FRMI software has been used to assess flood risk. The level of risk is based on a future projection to 2055 with RCP 8.5.

332. There are a large number of climate change adaptation design guides now issued by MRD and MPWT. These can be used when considering climate change adaptation measures.

333. Climate Change measures have been incorporated into the design. These include raising the heights of platform formation, increased heights of bunds around waste water treatment plant lagoons, raising the height of access roads and increased drainage.

334. The total cost of climate change adaptation measures in $3,185,000 out of a total project cost of US$82.2 million.

28.3. Additional Analysis Needed to be included in PAM TORs

335. Raising of road levels must be specified in detail during detailed design after the topographic survey.

28.4. Incremental Climate Change Costs of TLS2

336. Total base cost of the project is US$82.2 million inclusive of physical works, LAR and technical assistance (project implementation support, capacity building/training, social development).

This includes costs for climate resilience. Of this total figure Climate Change Resilience measures will result in the following costs to the project.

Stueng Saen:

1. Filling 3ha STP site with 50,000 m^{3} imported soil raise level by 3 m: $750,000
2. Filling to raise 1.1 km of 4m wide access road by 1.0-1.5 m: $180,000
3. Earthworks filling, stone pitching for slopes wave protection: $100,000
4. Earthworks filling for maturation ponds due to shallow depth: $70,000
5. Filling to raise STP internal site roads: $70,000

Sub-total Cost $1,170,000

Serei Saophoan:

1. Filling 3ha STP site with onsite & imported soil raise level by 3 m: $300,000

2. Filling to raise 1.4 km of 4m wide access road by 1.0-2.0 m: $380,000
3. Earthworks filling, stone pitching for slopes wave protection: $100,000
4. Earthworks filling for maturation ponds due to shallow depth: $70,000
5. Filling to raise STP internal site roads: $70,000

Sub-total Cost $920,000

Battambang:

1. Filling 10ha STP 20,000 m^3 imported soil site to raise level by 1.0-1.5 m: $350,000
2. Filling to raise 4 km of 4m wide access road by 0.5 m: $160,000
3. Earthworks filling at STP, stone pitching slopes for wave protection: $100,000
4. Filling to raise STP internal site roads: $70,000

Sub-total Cost $680,000

Sub Totals $2,770,000
Preliminaries (15%) $415,000

Total Cost Impact $3,185,000

29. ANNEX 6 WORKSHOP ATTENDANCE

29.1. Attendance Sheets

29.1.1. Attendees from Phnom Penh

LIST OF PARTICIPANTS AND CONTACT DETAILS

Venue and Date:

Phnom Penh Hotel, No. 53, Preah Monivong Blv, Phnom Penh, Kingdom of Cambodia

December 28, 2018

For Participants from Phnom Penh

No.	Name of participant	Sex	Position	Organisation	Location	Email	Phone Number
1.	Sum Cheat	M	Chef of Adaptation (MoE)	DCC, MoE	PP	Sumcheat@gmail.com	012850166
2.	Tep Phalkaroth	F	Vice-chief office	MOWRAM	PP	Tepphalkaroth@gmail	
3.	[illegible]	M	DDG	MLMUPC	PP	[illegible]	012603511
4.	Yentra Tan	M	MD	TANCONS	PP	tancons@online.com.kh	012 904 589
5.	David Lees	M	TL	"	"	DGL999@Yahoo.com	"
6.	Les Taylor	M	TL - Tonle Sap 2	SCE	PP	[illegible]	099 515 945
7.	Thap Solin	F	PMU Member	MPWT	P.P	thapsolin@gmail.com	017 883 445
8.	Seng Sraylap	F	official	MEF	PP		098 527855
9.	[illegible]	M	ENV/CC	OCSLUD	PP		011 956151
10.	Pou Manith	M	Deputy Director/[illegible]	MPWT	"		012 893 203
11.	~~[illegible]~~	~~M~~	~~Program officer~~	~~Family FM 99.5~~	~~P.P~~		~~[illegible]~~
12.	Cheng Chantha	M	Tancons		"	Chanthapos@yahoo.com	012895866
13.	Kethe [illegible]	M	Sr. Project Officer	ADB	PP		
14.	Sin Chanthnith	M	[illegible] Specialist	ADB - TSC	PP	[illegible]@gmail.com	092737773
15.	Mann Sochent	M	Operation Manager	TANCONS	PP	sochent.tancons@online.com.kh	085 175757
16.	Ty Younit	F	Admin	TANCONS	PP	younitty72@gmail.com	011 816757
17.	[illegible]LIKA	M	Translator team		PP		081333380
18.	Long Borith	M	~~TANCONS~~	TANCONS	PP		017 270004
19.							
20.							
21.							
22.							

Figure 29-1 Attendees from Phnom Penh

29.1.2. Attendees from Provinces

LIST OF PARTICIPANTS AND CONTACT DETAILS

Venue and Date:

Phnom Penh Hotel, No. 53, Preah Monivong Blv, Phnom Penh, Kingdom of Cambodia

December 28, 2018

For Participants from Province

No.	Name of participant	Sex	Position	Organization	Province	Email	Phone Number
1.	Keo Vetta	M	Chief [illegible]	DPWT Kg Chhnang	Kg Chhnang		078353906
2.	Keo Poru	M	Director	DPWT "	[illegible]		012788786
3.	Khut Khemra	M	staff	DPWT Kg Chhnang	"		089669917
4.	Kem Sokunthearoy	F	Deputy Director	DPWT Battambang	Battambang	[illegible]2015@gmail.com	092 8180[illegible]
5.	Say Pichenda	M	Chief office	DPWT SR	Siem Reap		012887486
6.	[illegible]						[illegible]
7.	Nop Chhaiuvtmara	M		DPWT B.T.B	B.T.B		017 280 860
8.	[illegible]		[illegible]		[illegible]		011749030
9.	[illegible]	F	[illegible]	DPWT BMC	BMC		012210015
10.	[illegible]	M	[illegible]	DPWT BMC	BMC		012686296
11.	[illegible]	M	[illegible]	[illegible]	B.B		013339936
12.	[illegible]	F	[illegible]	[illegible] MPWT	(P)		012997561
13.	KANG KIMCHHUN	M	Chief officer	Pursat DPWT	Pursat	Kimchhun.Kang@yahoo.fr	012 262 100
14.	CHHUY SOEURN	M	"	"	"		012564291
15.							

LIST OF PARTICIPANTS AND CONTACT DETAILS

Venue and Date:

Phnom Penh Hotel, No. 53, Preah Monivong Blv, Phnom Penh, Kingdom of Cambodia

December 28, 2018

For Participants from Province

No.	Name of participant	Sex	Position	Organization	Province	Email	Phone Number
1.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		015737430
2.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
3.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		012610279
4.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	011 88 65 88
5.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
6.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		012 75 25 07
7.							
8.							

Figure 29-2 Attendees from Provinces

29.2. Photos of Attendees

Figure 29-3 Photos of all Attendees


ADB
FINAL WORKSHOP
ON
H.E Vong Pisith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MEF