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

Climate Resilience Vulnerability Assessment Report

Prepared for

Ministry of Public Works and Transport (MPWT)

Cambodia

April 2018

SMEC
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CAM: Integrated Urban Environmental Management in the Tonle Sap Basin

Climate Resilience Vulnerability Assessment TLS1

April 2018

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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

0. Executive Summary

1. The Integrated Urban Environmental Management in the Tonle Sap Basin Project (the project or TLS1) will support the Government of Cambodia in improving urban services and enhancing climate resilience in two of the towns in the Tonle Sap Basin. These are Pursat and Kampong Chhnang.

2. The project focuses on improvement of flood protection, storm water drainage and solid waste management. Solid waste management will include improved collection and disposal at controlled landfills, although collection is not part of this project.

3. Kampong Chhnang and Pursat Urban areas in are interdependent with their respective surrounding rural communities, which are based on agriculture, fisheries and manufacturing. In perspective, about 12% of the overall population in the Tonle Sap Basin provinces live in urban areas. Urban areas are anticipated to grow by 40% by 2030 based on national census and National Institute of Statistics projections.

4. The TSUADF prioritizes Kampong Chhnang and Pursat municipalities because of their strategic importance, climate change risk and environment protection needs, and synergies with ADB agriculture and rural development projects. Increased prosperity and greater climate resilient infrastructure will strengthen rural-urban regional linkages in these towns through an integrated approach to urban environmental management.

5. Kampong Chhnang and Pursat urban development strategies list severe flooding and poor environmental sanitation as key infrastructure issues affecting residents' health and well-being. Both municipalities experienced severe flooding in 2011 and experience flooding 6–8 months each year.

6. In Kampong Chhnang, the annual hydrological cycle of the Tonle Sap is the main cause of flooding and inundation damage. In Pursat, lack of drainage causes the most inundation damage and affects 80% of the town. This is made worse by climatic conditions impacts with extreme rainfall events and limited facilities for solid waste management (SWM).

7. The most significant climate change risks associated with the sub-projects are during operation. Landfill sites can be impacted by heavy rain and flooding. However if effectively managed, the new facilities will bring about improvements to the living conditions of the population of the project areas.

8. The government has made progress in improving water supply and other municipal services, yet demand outstrips the government's ability to deliver. About 67% of households have access to piped water supply and 82% of the urban population has access to improved sanitation.

9. The solid waste management sector has not made the advances that the wastewater sector has in recent years. Whilst every provincial town has a solid waste facility at some level, they are not operating as controlled or sanitary landfills, but are uncontrolled dumpsites.

10. During the wet season the site access roads are often unusable and solid waste is dumped along these roads. There is currently very little solid waste management capacity and experience within Cambodia.

11. Flooding is an annual threat to most urban areas that have poor drainage systems. Existing flood risks will be exacerbated by climate change impacts.

12. The Project is being implemented in the towns of Kampong Chhnang and Pursat which are 90 km and 190 km from Phnom Penh respectively

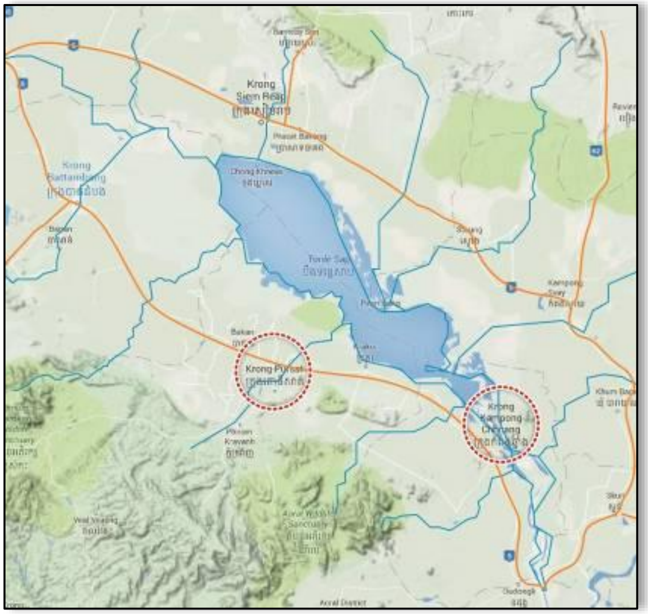


Figure 0-1 Location Map of Sub projects in TLS1

13. 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) Kampong Chhnang flooding reduced by 80%
- (iii) Pursat town center flooding reduced by 50%
- (iv) Improved SWM in for some 19,600 households
- (v) Sanitation coverage achieved for 90% of households
- (vi) Institutional framework and adaptive capacities of USUs strengthened in climate resilience infrastructure, climate change and hygiene awareness.

14. Kampong Chhnang urban area environmental improvements include

- Flood protection totaling 15.1 km along Tonle Sap riverbank through improvement of the existing embankment and construction of a new embankment where required

- 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.

15. Pursat 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).

16. The Tonle Sap Basin has an Urban Development Framework which guides climate resilient infrastructure development. Pursat and Kampong Chhnang each have their own Urban Development Strategies.

17. 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.

18. 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.
- 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.

19. 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.

20. 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 CRVA.

21. 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.

22. With respect to Time Steps much projected data is given as daily values but for design purposes often hourly or smaller time steps are recorded. IDF curves are available for Battambang. For the purposes of design correction factors obtained by extrapolating downwards the data for Battambang can be adopted.

23. 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.

24. 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.

25. The Tonle Sap Lake 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. It absorbs about 20% of the Mekong River's floodwaters. The Tonle Sap is connected to the Mekong River by the Tonle Sap River, which reverses its flow seasonally.

26. As a result of climate change impacts, 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, and the probability of river floods is likely to increase.

27. The project is still evolving and estimating the additional incremental cost of designs resulting from climate change is not simplistic. The design team have access to the data from the MRC Initial Studies Project (ISP) to assess Existing, Future and Residual Flood Risks in three Flood Focal Areas of the Lower Mekong Basin which is some cases results in a decrease of costs. These issues will need to be addressed by the detailed design consultants at some point in the future.

1. Introduction

1.1. Background

28. The Integrated Urban Environmental Management in the Tonle Sap Basin Project (the project or TLS1) will support the Government of Cambodia in improving urban services and enhancing climate resilience in two of the towns in the Tonle Sap Basin. These are Pursat and Kampong Chhnang.

29. The project focuses on improvement of flood protection, storm water drainage and solid waste management. Solid waste management will include improved collection and disposal at controlled landfills, although collection is not part of this project.

30. Since 2004 urbanization in Cambodia has taken place rapidly averaging 4.1% per year from 1998 to 2008 and steadily increasing from 19% to 24% and to 29% of Cambodia's population living in urban areas by 2014/15 (estimate 2015 by Cambodian Socio-Economic Survey by NIS). Urban areas of Kampong Chhnang and Pursat are expanding at a rate of about 2.1 % per annum, being crucial to the province and districts economic development and their integration into local and regional markets including the Greater Mekong Subregion (GMS) and the Association of Southeast Asian Nations (ASEAN). The project reflects principles of the Tonle Sap Urban Areas Development Framework (TSUADF) and strategies for Kampong Chhnang and Pursat urban development for the period from 2014 to 2030.

31. Urbanization has been taking place with nominal coordination and regulation, insufficient infrastructure and low regard for environmental impacts. This has resulted in inefficient unplanned growth, inefficient land use, damage and loss of natural resources, and inadequate access to urban services. Problems are attributable to low capacity in; urban management, strategic spatial planning, coordination and integration of environmental management in urban planning, and insufficient investment in infrastructure and community services. Strengthened urban planning and investments with effective operations and sustained maintenance are needed to accommodate expanding urban populations, sustain economic growth in urban areas, and protect the environment.

32. Kampong Chhnang and Pursat Urban areas in are interdependent with their respective surrounding rural communities, which are based on agriculture, fisheries and manufacturing. In perspective, about 12% of the overall population in the Tonle Sap Basin provinces live in urban areas. Urban areas are anticipated to grow by 40% by 2030 based on national census and National Institute of Statistics projections.

33. The TSUADF prioritizes Kampong Chhnang and Pursat municipalities because of their strategic importance, climate change risk and environment protection needs, and synergies with ADB agriculture and rural development projects. Increased prosperity and greater climate resilient infrastructure will strengthen rural-urban regional linkages in these towns through an integrated approach to urban environmental management.

34. Kampong Chhnang and Pursat urban development strategies list severe flooding and poor environmental sanitation as key infrastructure issues affecting residents' health and

well-being. Both municipalities experienced severe flooding in 2011 and e x p e r i e n c e flooding 6–8 months each year. In Kampong Chhnang, the annual hydrological cycle of the Tonle Sap is the main cause of flooding and inundation damage. In Pursat, lack of drainage causes the most inundation damage and affects 80% of the town. This is made worse by climatic conditions impacts with extreme rainfall events and limited facilities for solid waste management (SWM). 'Reduce, reuse, recycle' for waste management is active in both municipalities through junk shops and waste pickers, but only about 20% of the waste stream in Kampong Chhnang and 30% in Pursat is recycled.

35. During the wet (flooding) season, poor and vulnerable communities are cut-off from the town center, restricting their access to markets and social services. They reside in low-lying areas near the Tonle Sap with poor drainage, and have limited access to SWM services and sanitation, making human waste disposal an environmental issue especially for communities living on, and adjacent to, the Tonle Sap. About 61% of households in Pursat and 50% in Kampong Chhnang have access sanitary latrines. The Identification of Poor Households Programme (IDPoor) identified 2,133 poor households in Kampong Chhnang and 3,456 poor households in Pursat project area. The project will use this program in supporting community initiatives in conjunction with the Community Mobilization and Environmental Improvements (CMEI) program activities addressing climate change and environmental needs for the urban poor and vulnerable.

36. 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.

37. The most significant climate change risks associated with the sub-projects are during operation. Landfill sites can be impacted by heavy rain and flooding. However if effectively managed, the new facilities will bring about improvements to the living conditions of the population of the project areas.

1.2. Design Issues

38. In 2014, about 22% of Cambodia's 15 million people lived in urban areas. The urban population is growing at an average of 2.6% per annum while rural areas are being integrated into urban areas.[1]

39. The government has made progress in improving water supply and other municipal services, yet demand outstrips the government's ability to deliver. About 67% of households have access to piped water supply and 82% of the urban population has access to improved sanitation.

40. The solid waste management sector has not made the advances that the wastewater sector has in recent years. Whilst every provincial town has a solid waste facility at some level, they are not operating as controlled or sanitary landfills, but are uncontrolled dumpsites.

[1] National Institute of Statistics. Ministry of Planning, October 2015

41. During the wet season the site access roads are often unusable and solid waste is dumped along these roads. There is currently very little solid waste management capacity and experience within Cambodia.

42. Flooding is an annual threat to most urban areas that have poor drainage systems. Existing flood risks will be exacerbated by climate change impacts.

1.3. The Project

43. 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 - as shown in the Figure 1-1.

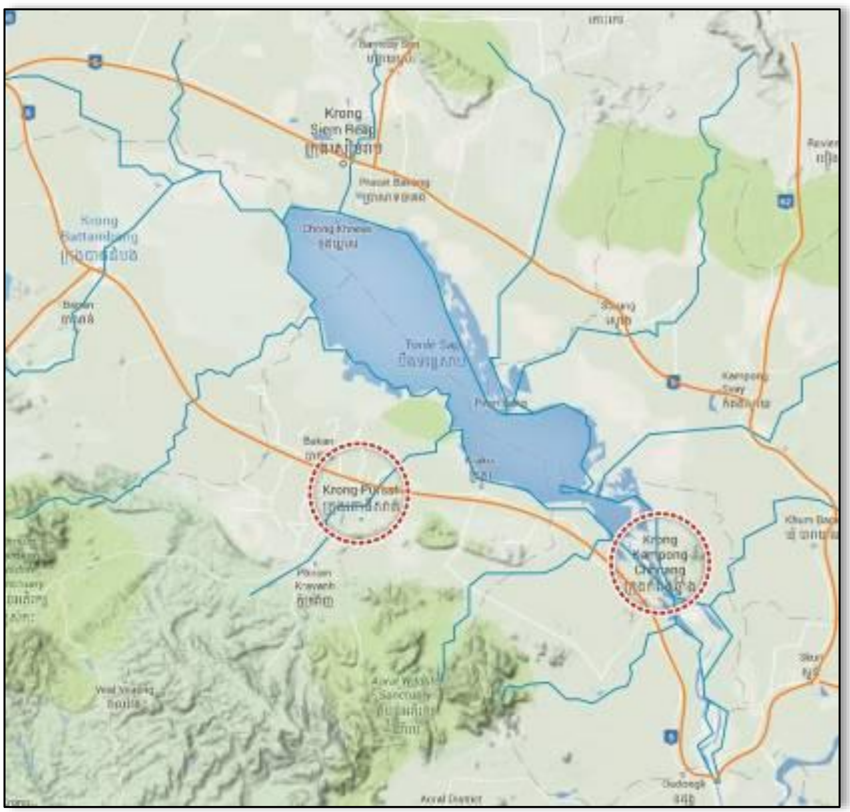


Figure 1-1 Location Map of Sub projects in TLS1

1.3.1. Kampong Chhnang

44. 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.

45. 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.

1.3.2. Pursat Town

46. 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.

47. 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.

1.3.3. Project Outcomes

48. 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:

- (vii) The Project benefits 100,000 residents in Kampong Chhnang and Pursat
- (viii) Kampong Chhnang flooding reduced by 80%
- (ix) Pursat town center flooding reduced by 50%
- (x) Improved SWM in for some 19,600 households
- (xi) Sanitation coverage achieved for 90% of households
- (xii) Institutional framework and adaptive capacities of USUs strengthened in climate resilience infrastructure, climate change and hygiene awareness.

1.4. Kampong Chhnang Designs

49. Kampong Chhnang municipality has stated that the annual flooding from the Tonle Sap River is a major obstacles to economic development and has prioritized raising and upgrading the existing embankment to the North and East of the town.

50. Also improvement of environmental sanitation for the large communities living on and adjacent to Tonle Sap will alleviate difficulties caused by this annual event.

51. Kampong Chhnang urban area environmental improvements include

- Flood protection totaling 15.1 km along Tonle Sap riverbank through improvement of the existing embankment and construction of a new embankment where required
- 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.

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

53. Embankment protection will prevent flooding from the Tonle Sap into Kampong Chhnang town, reducing its vulnerability to flooding and providing protection to 1 in 50 year high water levels.

54. In the dry season, outlets will accommodate the natural streams flowing into the Tonle Sap, and sluice gates will avoid backflow into the town as the water rises. In the wet season, natural retention areas will retain wet season flows. The additional provision of design and construction of pumping stations for the outlets, may be retrofitted, if requested, after the municipality-driven urban development planning is confirmed,

Figure 1-2 Location of Embankment and Landfill Sites

55. The embankment is imperative for residents to have continued access to social services and economic activities in the town (e.g., rice processing mills). Improved flood protection will assist farmers in the eastern part of the municipality to increase agricultural production from two to three crops per year.

Figure 1-3 Site for New Landfill

Figure 1-4 Terrain behind New Landfill

Figure 1-5 Existing Embankment

Figure 1-6 Alignment of New Embankment

1.5. Pursat Designs

56. Pursat Municipality has already prioritized and initiated implementation of flood protection by raising and strengthening the Pursat river embankments in the town centre. It plans to continue building more riverbank protection groynes to prevent embankment erosion, and to rehabilitate and extend the existing drainage system by installing more road side drains. There will also be an improvement in Solid Waste Management (SWM).

57. Pursat 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).

58. 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.

59. 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.

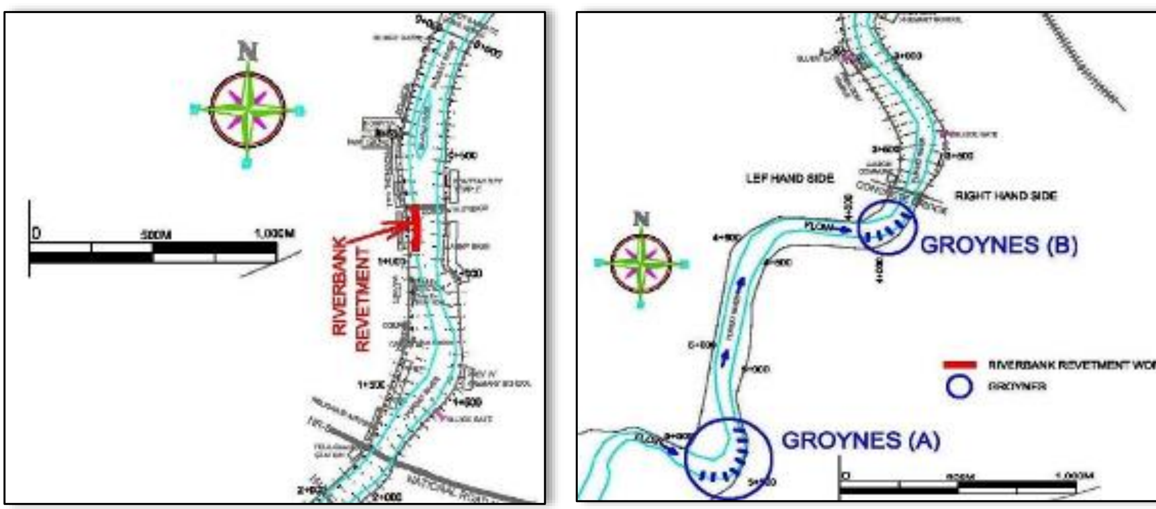


Figure 1-7 Riverbank protection work Revetments

60. The landfill sites are shown below.

Figure 1-8 Landfill Sites

Figure 1-9 Proposed Site Septage Treatment Plant

Figure 1-10 Irrigation Canal for Outfall

Figure 1-11 River Bank Erosion

Figure 1-12 New Landfill Site

1.6. Schedule

61. The indicative construction schedule for the subprojects is given in Annex A.

2. Climate Change

2.1. Climate Change Impacts in Sanitation Sector

62. As stated in the "Guidelines for Climate Proofing Investments in the Water Sector: Water Supply and Sanitation, Climate Impacts", ADB 2016 there may be impacts from climate change on wastewater treatment and solid waste disposal. [2]

Table 2-1 Impacts from Climate Change on Sanitation Infrastructure

Warmer Temperatures	• Increased operating challenges to biological and chemical processes of treatment facilities. • Increased temperatures and increased evaporation in receiving water bodies, changing chemical balances and increased eutrophication. • Reduced capacity to meet wastewater treatment requirements and standards
More Frequent and/or Intense Extreme Weather Events	• Increased risk of direct flood damage to treatment plant, pumping and conveyance, and outfall. • Increased risk of untreated sewage overflows contaminating water supply sources. • Changes in quantity and quality of watershed runoff and in the resulting non-point source pollution loads to receiving waters.

2.2. Climate change impacts and Floods

63. The Tonle Sap Lake is connected to the Mekong River by the Tonle Sap River. About 62% of the Tonle Sap's water originates in the Mekong River and 38% in the Tonle Sap basin. The basin absorbs about 20% of the Mekong River's floodwaters, which reverses its flow seasonally.

64. Average water levels in the Tonle Sap Lake 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 and adversely impact the urban community socio-economic environments due to lack of protective infrastructure and climate resilient operational management systems.

[2] Sources: Cromwell, Smith, and Raucher (2007); Water Environment Research Foundation, (2010); O'Neill (2010); Major et al. (2011).

3. Climate Change Literature Review

65. The climate risk assessment has been undertaken in accordance with ADB's guidelines and international practices. The consultants have taken account of the following publications:

- Mekong River Commission, Roads and Floods, MRC Technical Paper No. 35, 2011
- Guidelines for Climate Proofing Investments in the Water Sector: Water Supply and Sanitation, Climate Impacts, ADB 2016
- Guidelines for Climate Proofing Investment in the Transport Sector - Road Infrastructure Projects, August 2011, ADB.
- 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
- Climate Change Resilient Roads, MRD October 2014
- Climate Change Action Plan for Transport Sector 2014-2018 MPWT
- Report on Knowledge Management, MPWT, June 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
- Vulnerability Mapping Report, MPWT, January 2016
- Climate Modeling Report, MPWT, January 2016
- Flood Risk Management Interface (FRMI) Version 1.2 obtained from MPWT September 2016
- Update Report Flood Risk Management Interface (FRMI) January 2018
- National Adaptation Plan Process in Cambodia. General Secretariat of National Council for Sustainable Development/Ministry of Environment, Kingdom of Cambodia, Phnom Penh. May 2017
- Cambodia's Clean City Program for Sustainable Cities. 2018
- Community Based Disaster Risk Management (Pursat), ICEM, 2018

66. These documents reflect the latest state of knowledge and "good practice" on climate change in Cambodia.

67. The Flood Risk Management Interface (FRMI) is the MPWT in-house software used for determining the magnitude of flood risk plus indicative costs of adaptation measures based on known unit rates. Version 1.2 was used although it is understood that Version 2.0 has been prepared but not released for general use yet. The MPWT FRMI software has been used in this evaluation.

4. Climate Change Science

4.1. IPCC

68. 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. Future Scenarios

69. 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.

70. 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.

71. 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.

72. 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".

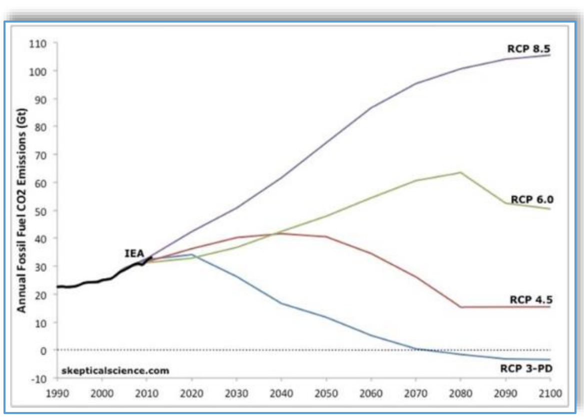


Figure 4-1 RPCs from IPCC AR5 (2011)

4.3. General Circulation Models used in the Region

73. 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.

74. 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.

75. 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.

4.4. Downscaling General Circulation Model outputs to regional scales

76. 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.

4.5. Projected Temperature change

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

4.6. Projected Rainfall Change

78. 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.

79. The model projects 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.

4.7. Rainfall Intensity

80. 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.

81. 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

82. 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.

5.2. Climate data provided for Risk Analysis

83. The data in the FRMI consists of:

- 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.

5.3. Current 1 Day Extreme Rainfall

84. 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.

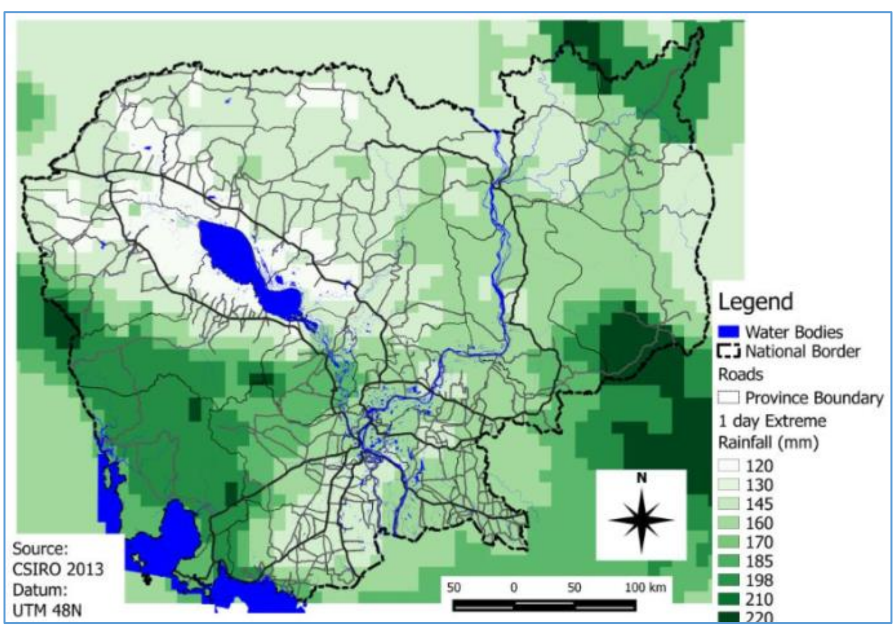


Figure 5-1 Current 1 day extreme rainfall from the CCAM model.

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

85. 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.

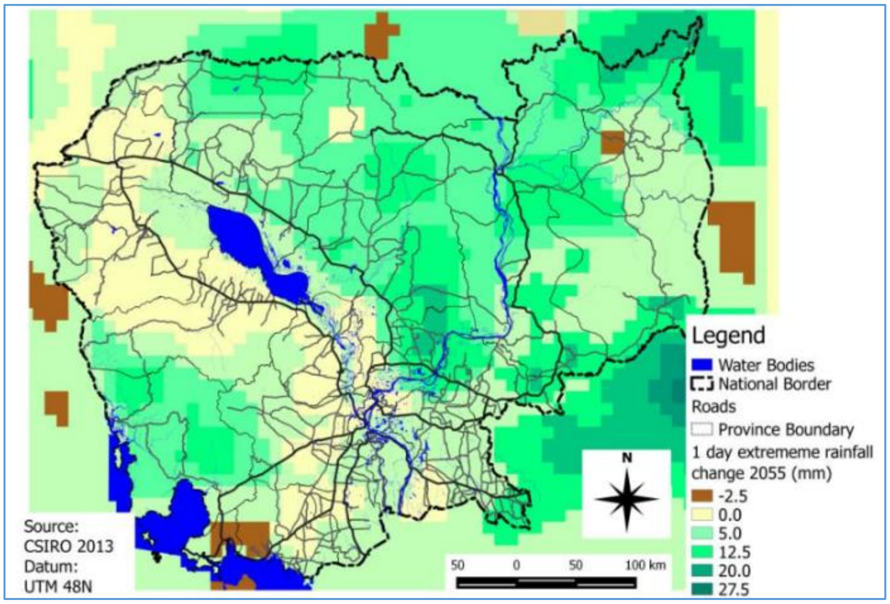


Figure 5-2 Projected change in 1 day extreme rainfall for 2055 (RCP 8.5 from CCAM)

5.5. Current 5 day Extreme Rainfall

86. 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. 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.

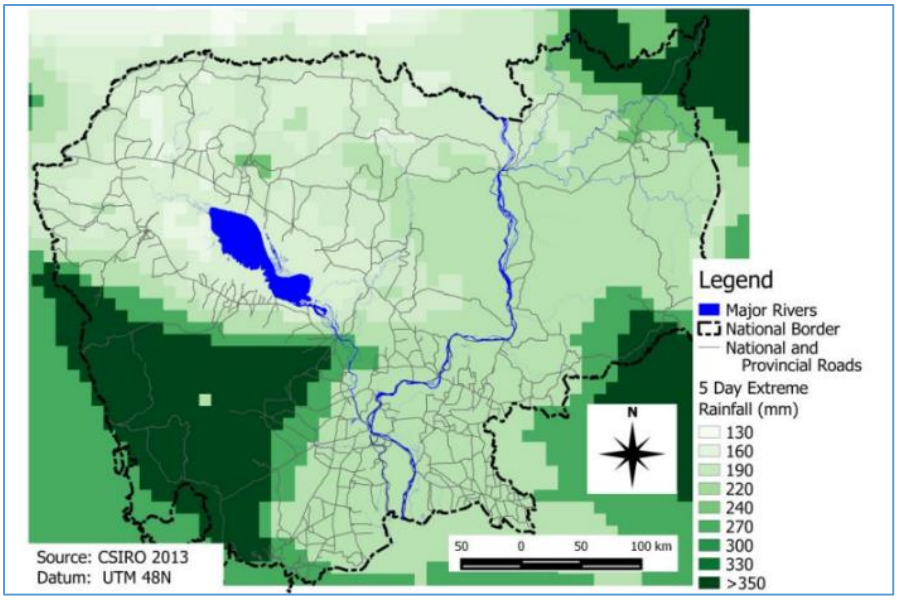


Figure 5-3 Current 5 day extreme rainfall from CCAM

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

87. 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.

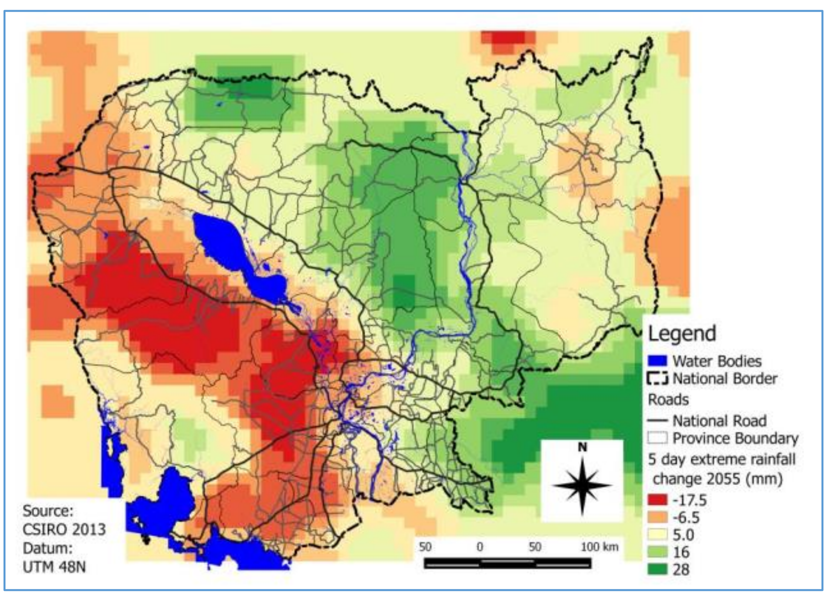


Figure 5-4 Projected change in 5 day extreme rainfall for 2055 (RCP 8.5)

5.7. Changes to 1-day Precipitation

88. 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%).

5.8. Changes to 5-day Precipitation

89. 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.

6. Climate Projections

6.1. Cambodia - Lower Mekong Basin

90. Under USAID Mekong ARCC project, 2013 ICEM carried out downscaled projections for different areas of the Mekong basin, including Cambodia.[3] Figure 6-1 and 6-2 show the changes in average maximum daily temperatures in the dry season and wet season.

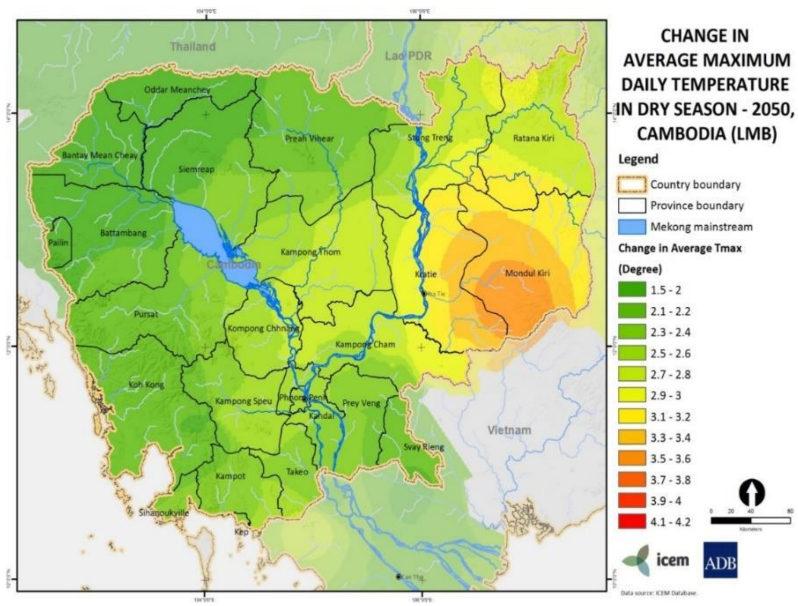


Figure 6-1 Change in average maximum daily temperature in the dry season – 2050

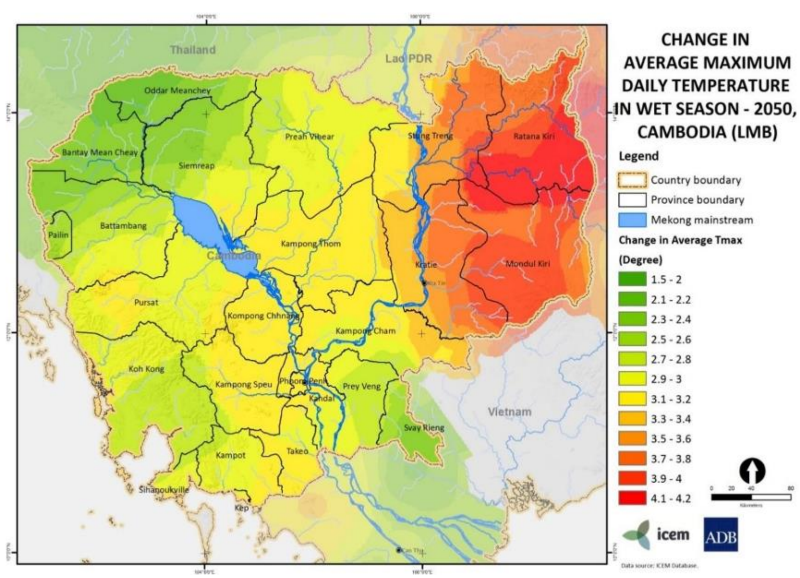


Figure 6-2 Change in average maximum daily temperature in the wet season by 2050

[3] USAID Mekong ARCC Climate change Impact and Adaptation Study for the Lower Mekong Basin. ICEM. 2013.

91. 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 6-3, 6-4) and drier dry seasons. (Figure 6-5)

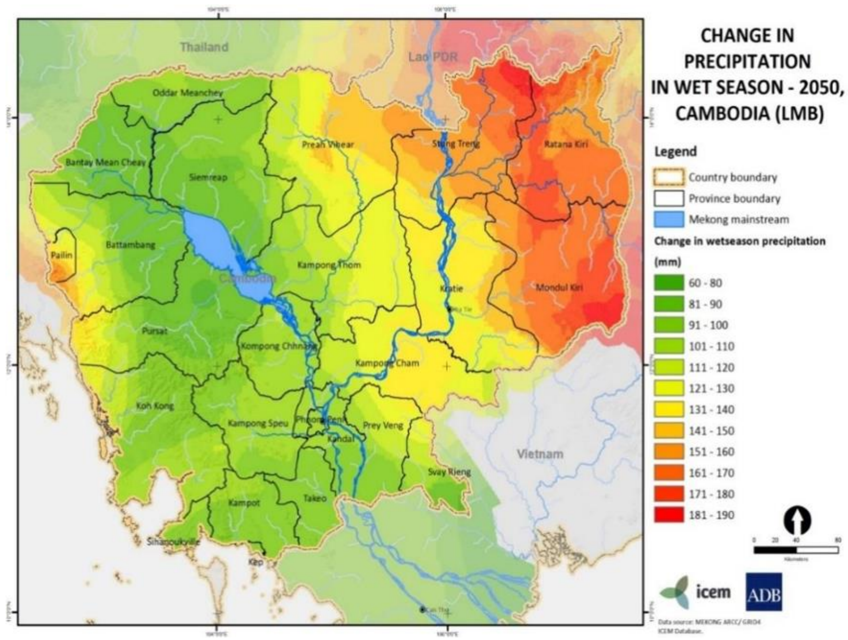


Figure 6-3 Increase in rainfall in the wet season – 2050

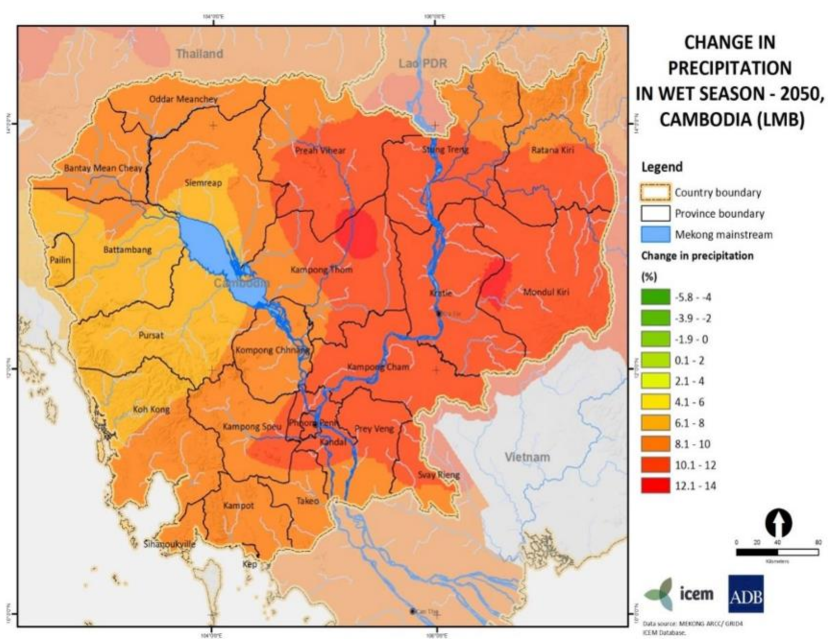


Figure 6-4 % change in rainfall in wet season – 2050

92. 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 6-5). However some including Pursat may receive slightly more (2mm) in the dry season.

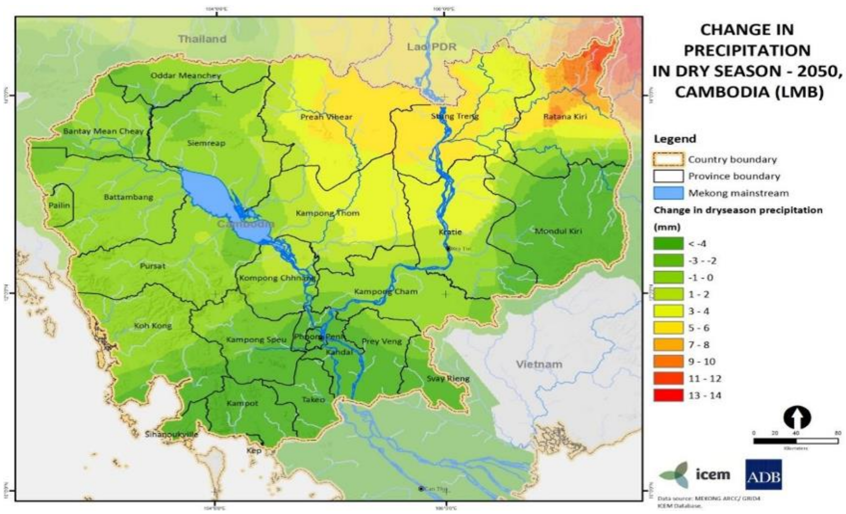


Figure 6-5 Change in rainfall during the dry season - 2050

93. 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 each year predicted in some provinces. (Figure 6-6).

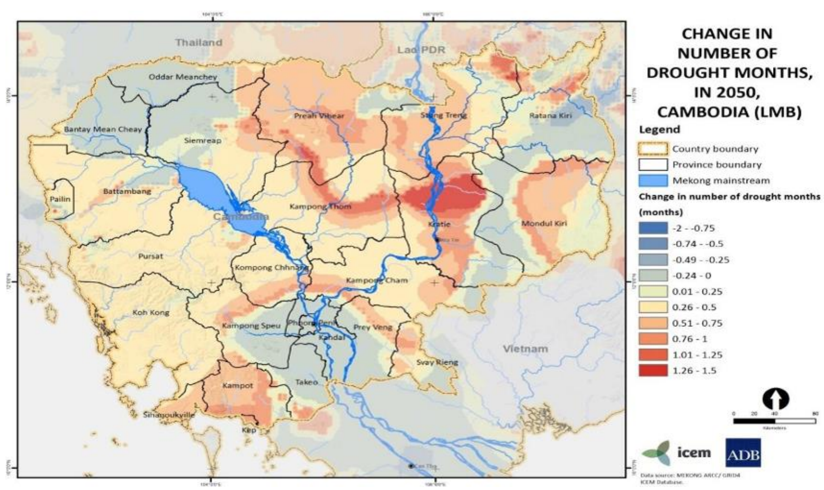


Figure 6-6 Change in number of drought months per year

94. 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 in the Tonle Sap and Mekong

delta floodplains may experience significant increases of extreme floods with depths 2.0m (Figure 6-7).

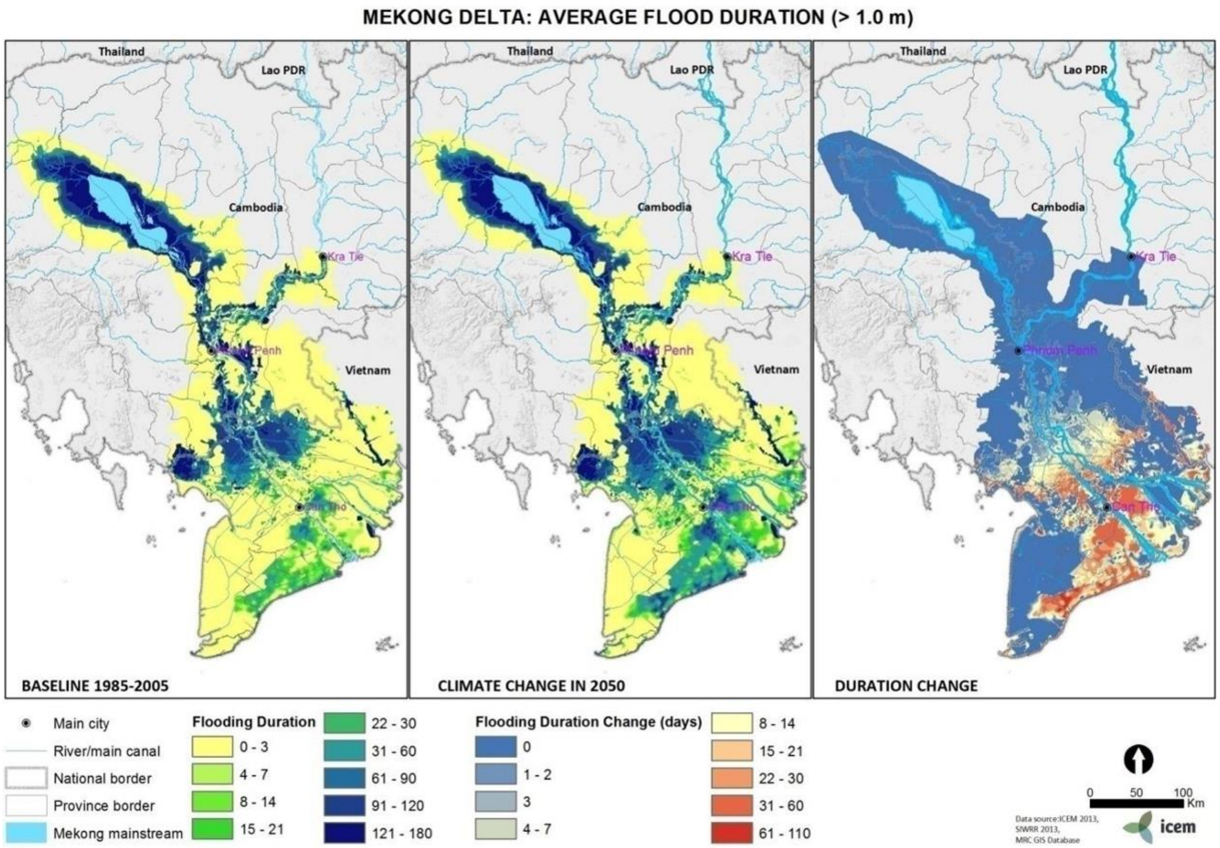


Figure 6-7 Projected flooding in the Mekong delta and floodplain – 2050

6.2. Flooding

95. 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.

96. 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.

97. 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.

98. In rural areas flooding is a major problem. In some upland areas with significant slopes and a water course, the type of flooding is flash flooding which occurs over several hours. 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.

99. 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.

6.3. Drought and Climate Change

100. These longer periods between rainfall increase 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.

7. Flood Risk Management Interface - FRMI

7.1. Background

101. 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.

102. The improvement of access to knowledge, to its dissemination and its conservation was addressed by the development of a knowledge management tool called Flood Risk Management Interface (FRMI). This software provides easy access to information about floods and flood risk maps.

7.2. FRMI Methodology

103. 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.

104. For this study road segments close to the planned infrastructure such as STPs or landfills have been identified and the risk of flooding associated with this area used in the assessment.

7.3. SRTM Accuracy

105. The approximate accuracy of a 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.

106. 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.

7.4. Flood Risk Damage Maps

107. Flood risk damage maps have been produced for various types of floods. The vulnerability maps present four 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. The overall equation is :

Flood damage risk = Risk of flood occurrence x condition factors

7.5. Applicability of FRMI Flood Risk Damage Maps to TLS2

108. The FRMI software covers the whole of Cambodia and is based on topographical information from maps which have a 90m resolution. This is not suitable for detailed design.

However FRMI is intended to be used as a screening tool, such as is needed in Preliminary Design, not in the later stages of detailed design. Although the 90m resolution can be considered coarse, given the lack of abrupt changes in gradients in Cambodia and the absence of steep crevasses or rapid changes in slope in mountainous or hilly areas, the given resolution should not significant errors into any conclusions drawn from the use of FRMI.

109. An updated version based on 30 m resolution is under preparation but was not available at the time of this report preparation.

8. Climate Change by Province

8.1. Risk Information from FRMI related to TLS1 by Province

110. The climate change parameters are discussed below. Flood Risk maps are shown for each location. The flood risk is given for the year 2055 under Climate Change Scenario RCP 8.5. This is a conservative (pessimistic) scenario.

8.2. Kampong Chhnang, Kampong Chhnang Province

8.2.1. Climate Change Projections

111. 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.

8.2.2. Rainfall Data for Kampong Chhnang

112. 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.

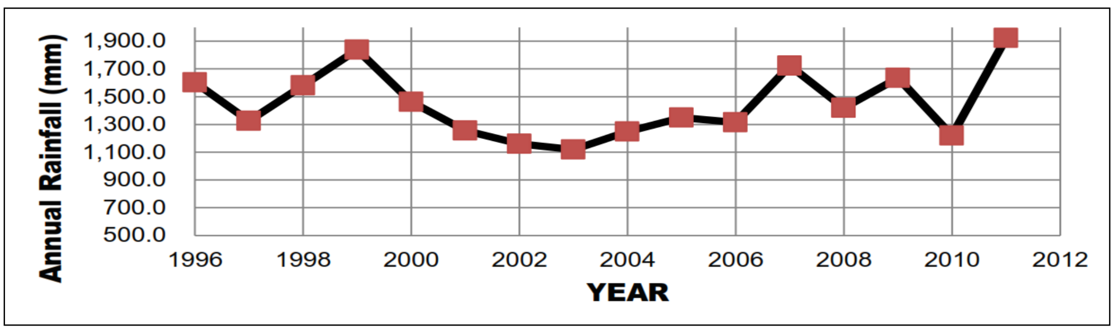


Figure 8-1 Annual Rainfall in Kampong Chhnang

113. 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[4]. These dams could have a substantial impact on the Mekong's hydraulic regime.

8.2.3. NASA NEX Data

114. 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

[4] Annual Flood Report and Yearbook, MRCS, Vientiane, 2008.

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 CRVA. Data produced is given below.

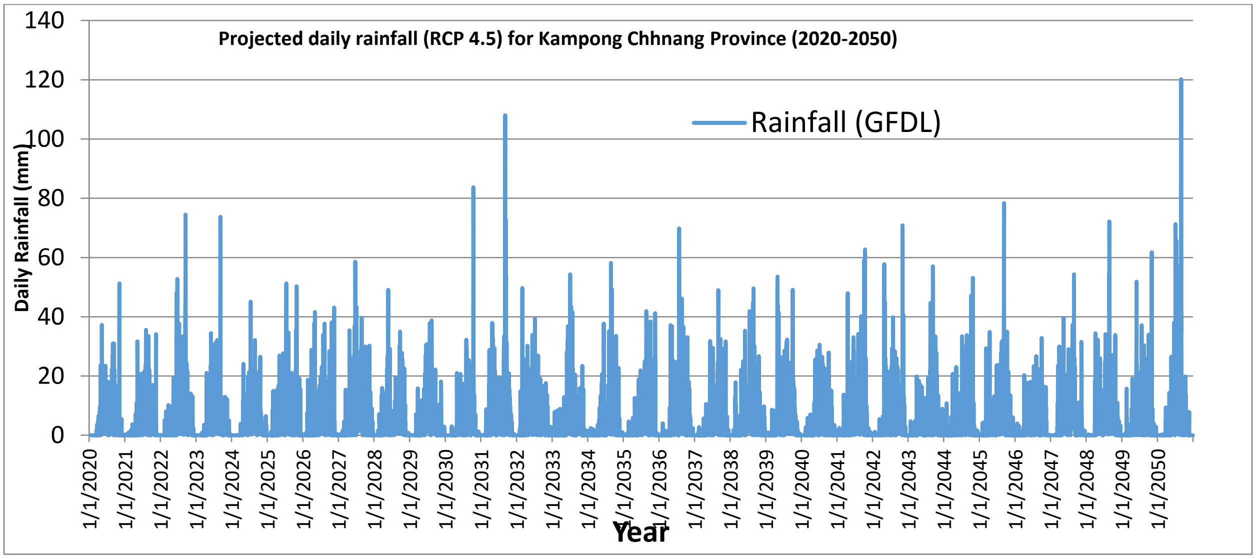


Figure 8-2 Projected daily rainfall (RCP 4.5) for Kampong Chhnang Province (2020-2050)

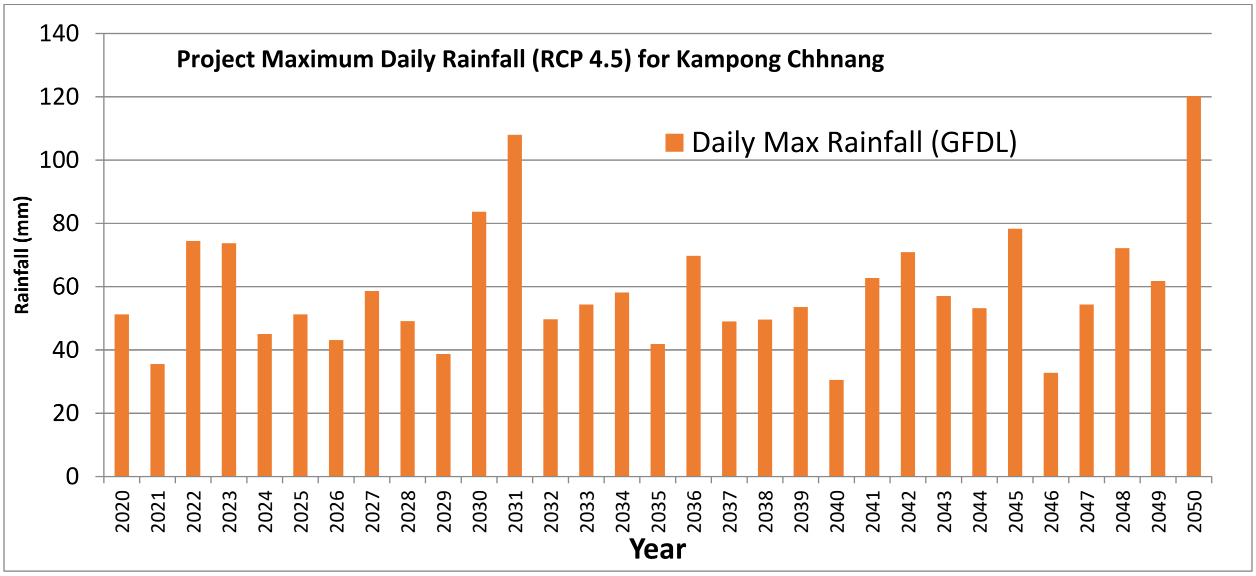


Figure 8-3 Project Maximum Daily Rainfall (RCP 4.5) for Kampong Chhnang

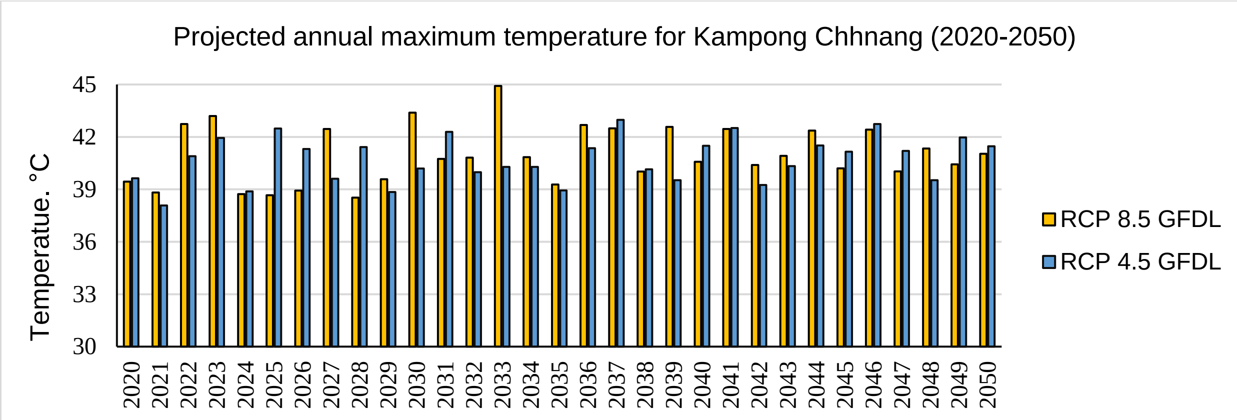


Figure 8-4 Projected annual maximum temperature for Kampong Chhnang (2020-2050)

8.2.4. Threat Profile Kampong Chhnang

The Kampong Chhnang Province threat profile is given below :

Summarized data up to 2050:

Variable	Dry season			Wet season		
	Baseline	2050	Changes	Baseline	2050	Changes
Maximum temperature	30.1 °C	32.6 °C	2.5 °C	28.2 °C	31.3 °C	3 °C
Precipitation	232 mm	231 mm	-0.3 %	1144 mm	1248 mm	9.1 %

Potential threats from projected climate change by 2050:

- Significantly hotter and wetter in the wet season
- Significantly hotter and slightly dryer in the dry season

Potential impacts from the climate change threats by 2050:

- Significantly hotter and wetter in the wet season
  - Increased severity of pluvial flooding (where flooding already occurs)
  - Potentially new areas of pluvial flooding
  - Increased flows of the Mekong River
  - Floods would be deeper and longer
  - Heat-related stresses
    - increase pace of infrastructure degradation
    - crop failure and livestock losses
    - potential health problems
- Significantly hotter and slightly dryer in the dry season
  - Heat-related stress: infrastructure, agriculture, health
  - Higher evaporation, lower rainfall: increased incidence and duration of drought
  - Water stress for agriculture & domestic use

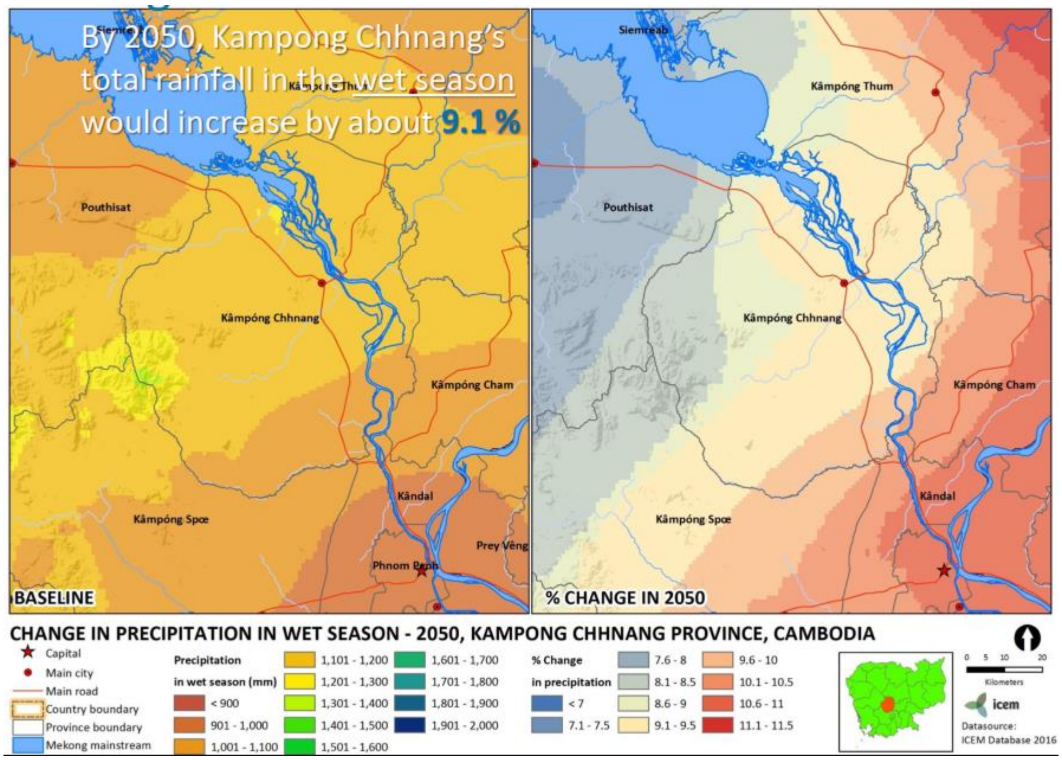


Figure 8-5 Changes in Rain fall in Wet Season

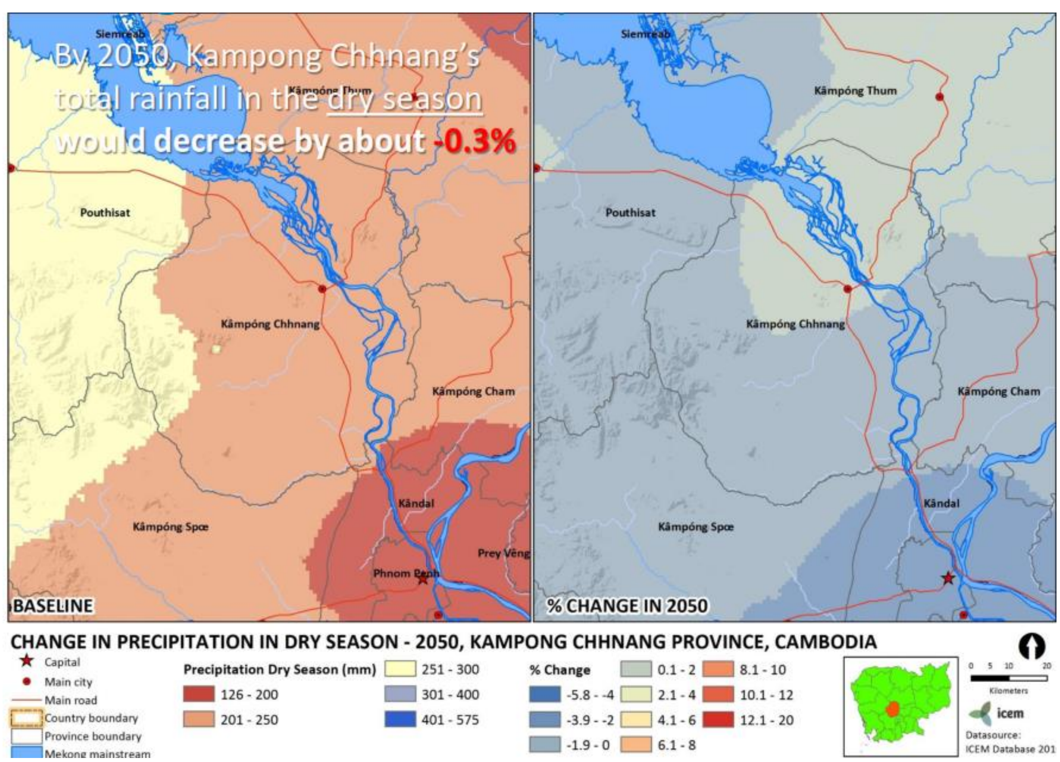


Figure 8-6 Changes in Rain fall in Dry Season

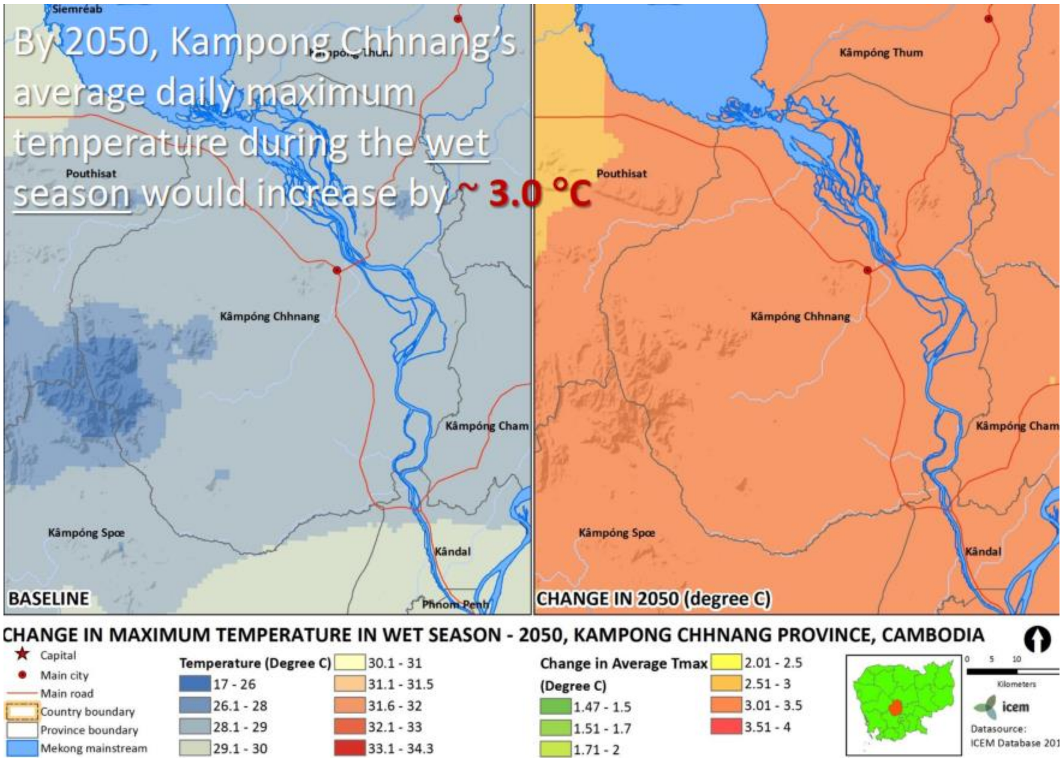


Figure 8-7 Changes in Temperatures in Wet Season

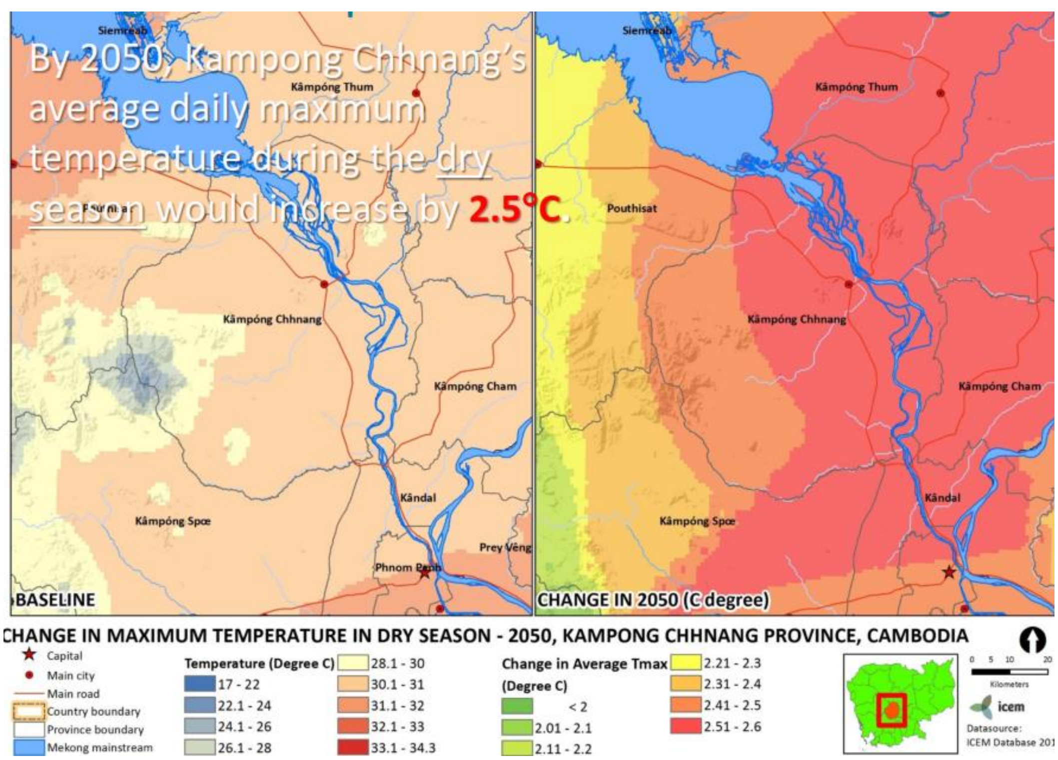


Figure 8-8 Changes in Temperatures with Climate Change

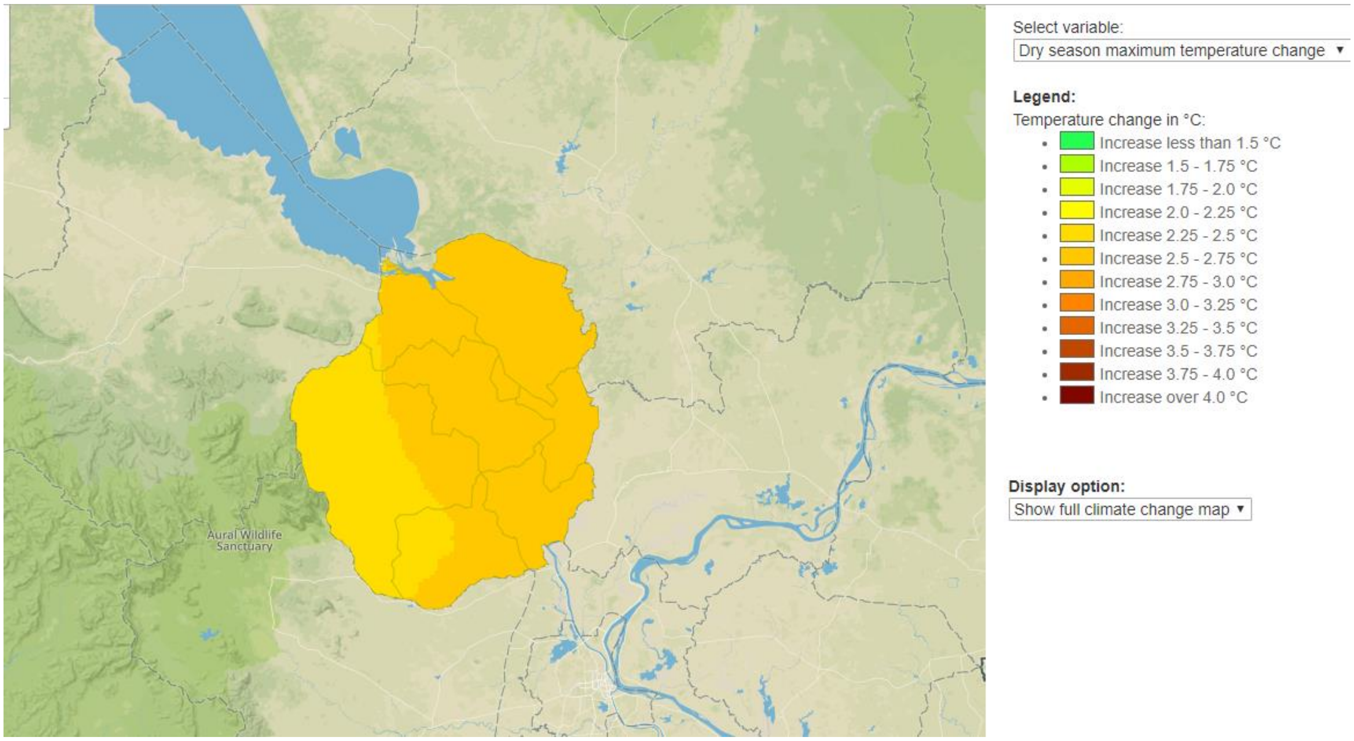


Figure 8-9 Dry Season Maximum Temperature Change

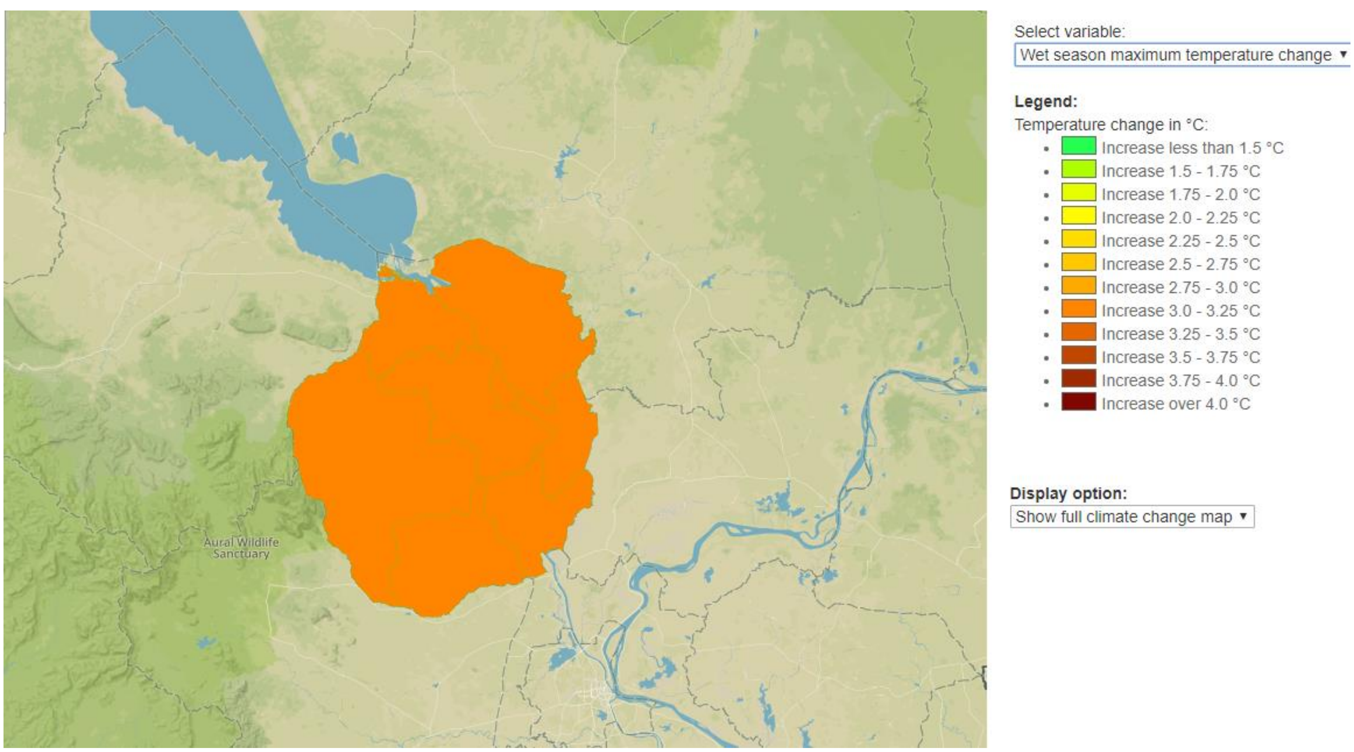


Figure 8-10 Wet Season Maximum Temperature Change

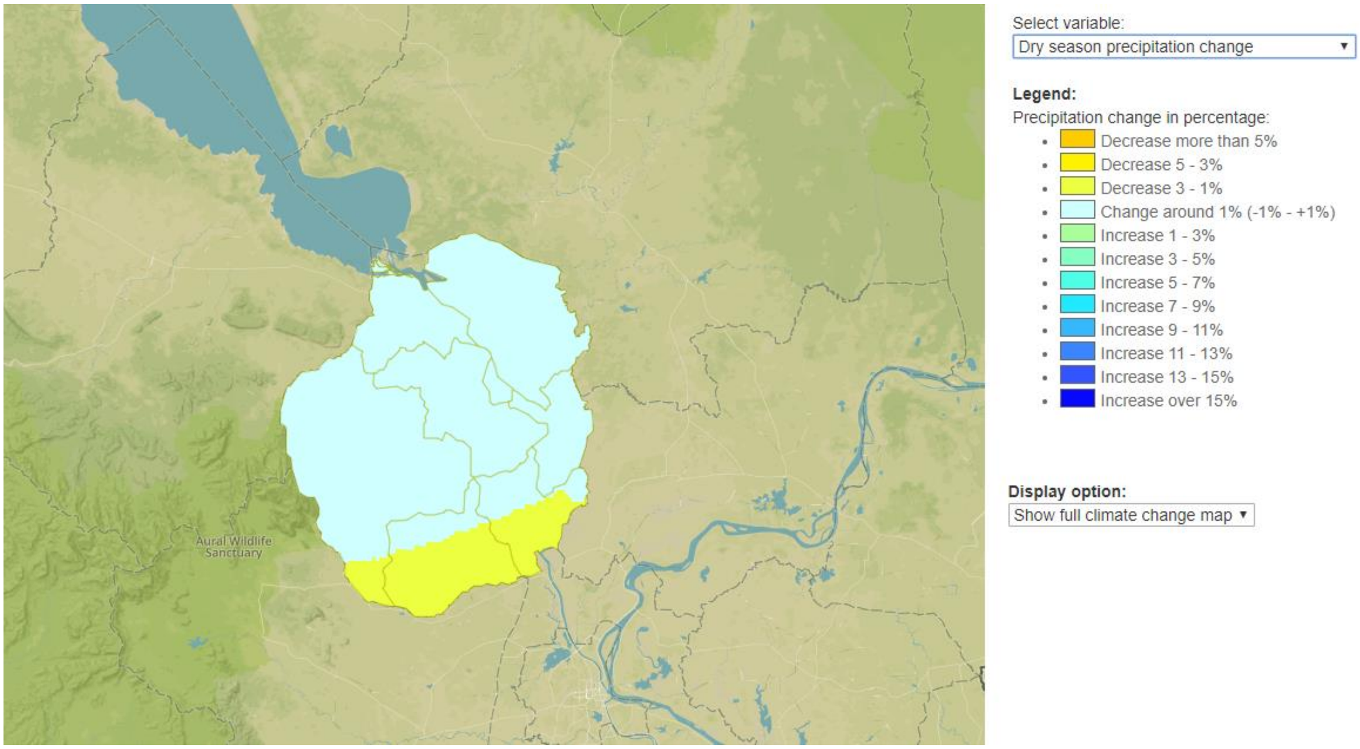


Figure 8-11 Dry Season Precipitation Change

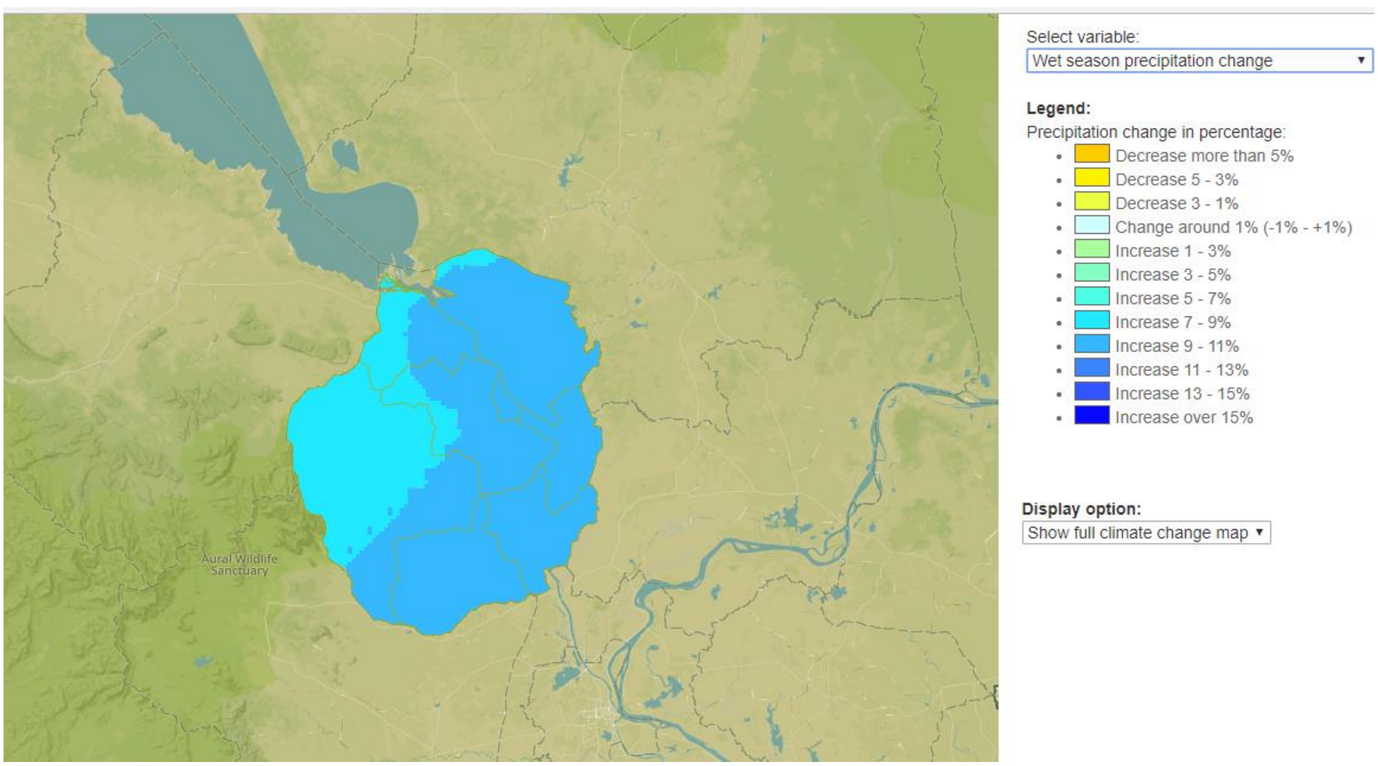


Figure 8-12 Wet Season Precipitation Change

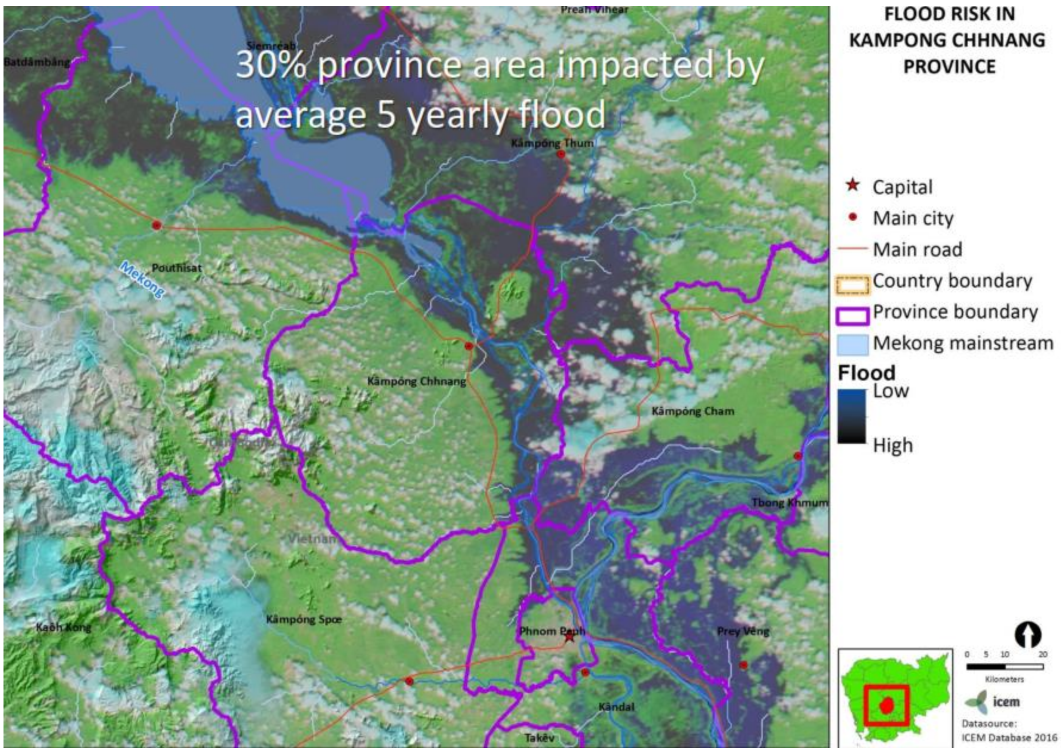


Figure 8-13 Changes in Floods with Climate Change

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

8.2.5. FRMI Climate Change Risks

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

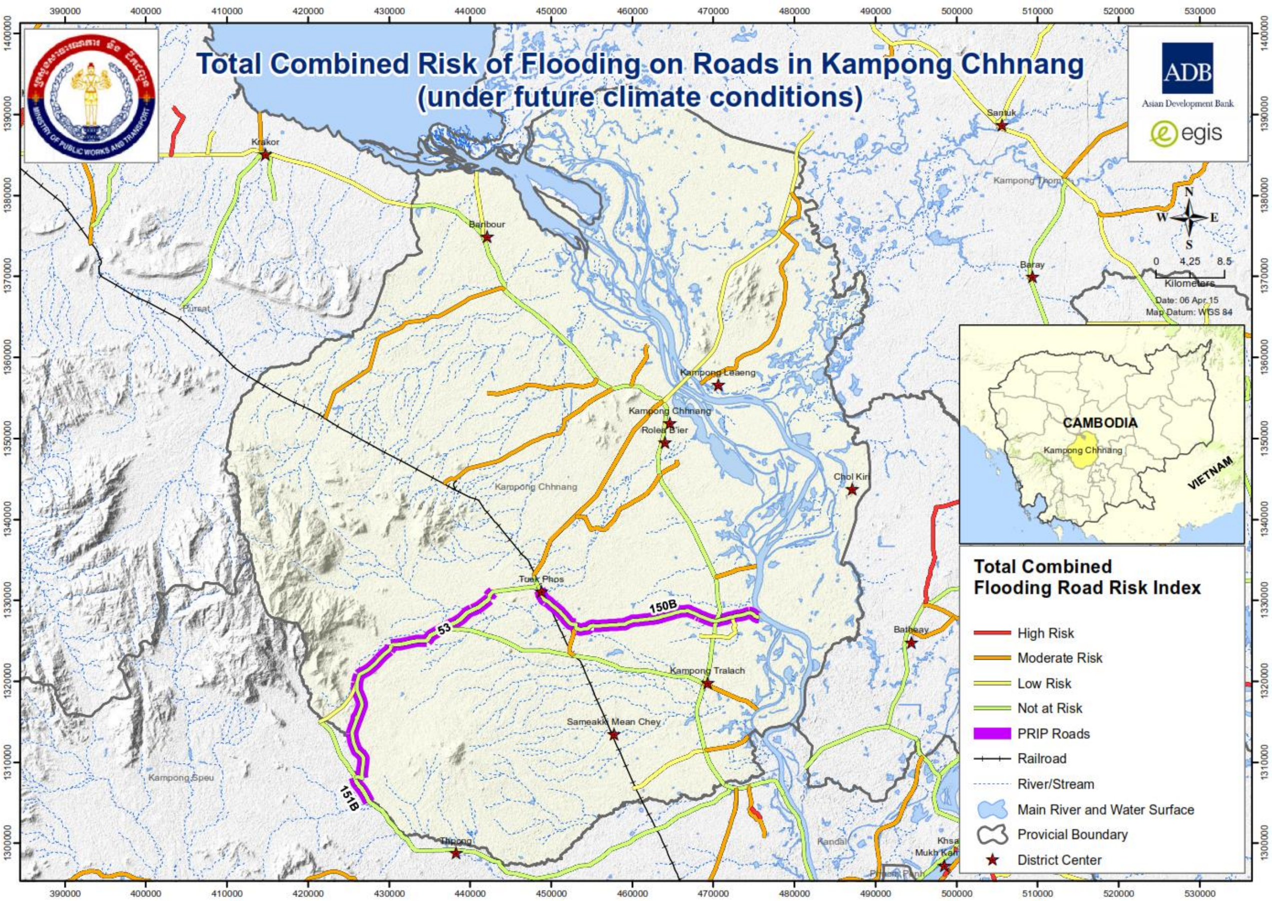


Figure 8-14 FRMI Flood Risk Map Kampong Chhnang Province

116. The sites are in locations that are classified as being at **Low to Moderate Risk** of flooding.

8.3. Pursat

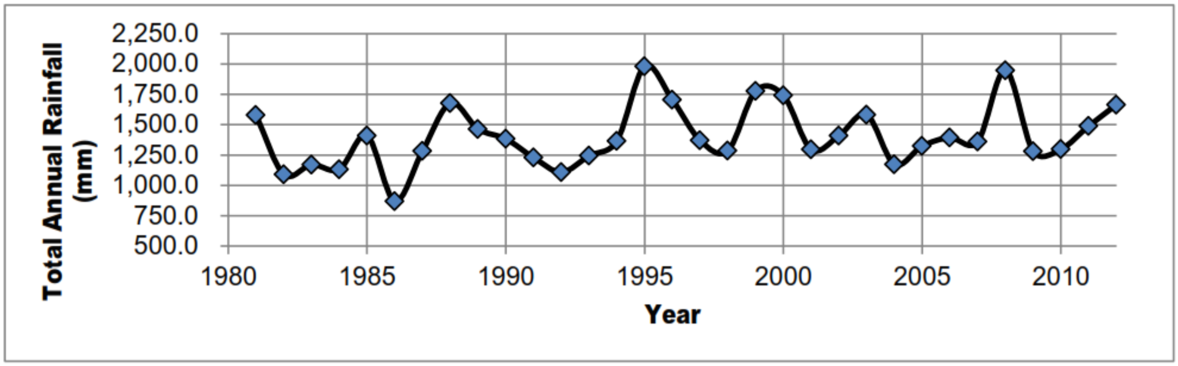
8.3.1. Climate Change Projections

117. 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.

118. 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.

8.3.2. Rainfall Data Pursat

119. 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 8-15 Total Annual Rainfall in Pursat

8.3.1. NASA NEX Data

120. 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 CRVA. Data produced is given below.

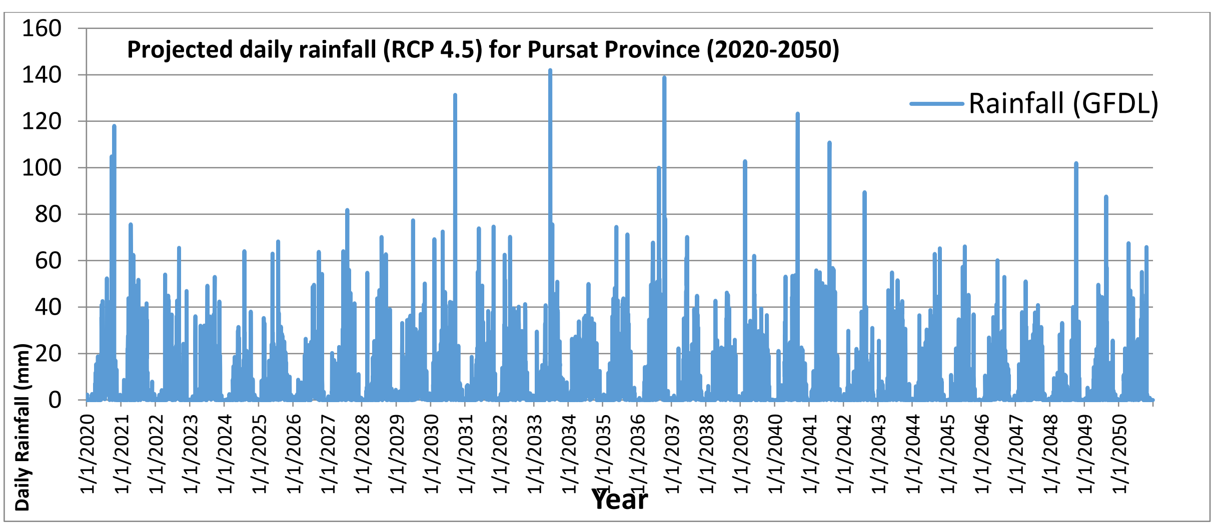


Figure 8-16 Projected daily rainfall (RCP 4.5) for Pursat Province (2020-2050)

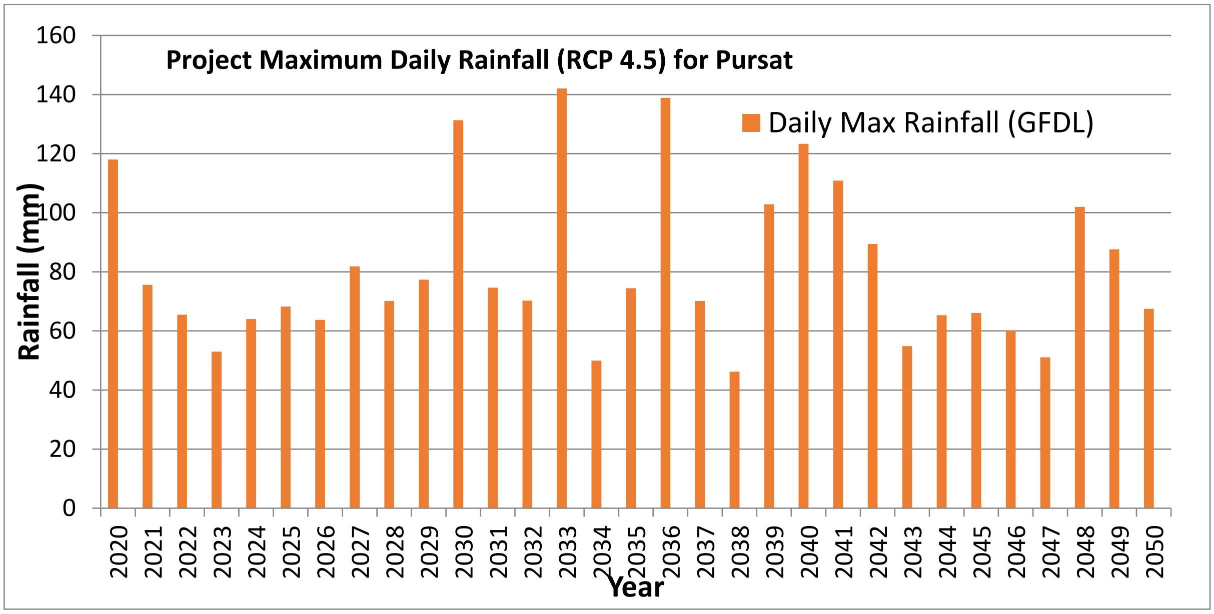


Figure 8-17 Project Maximum Daily Rainfall (RCP 4.5) for Pursat

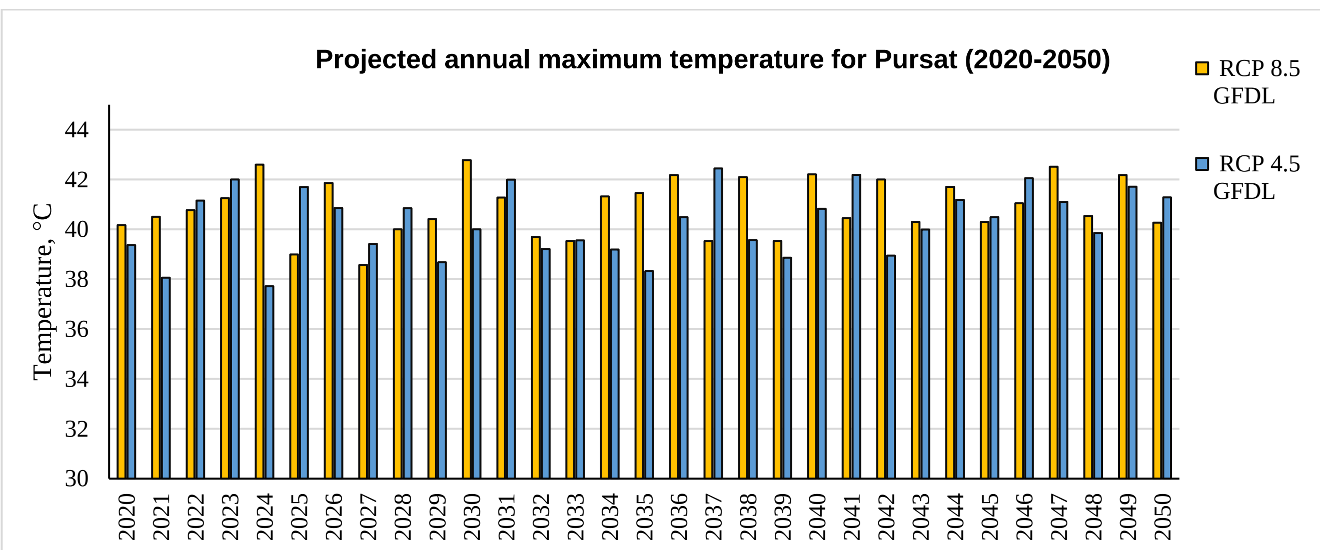


Figure 8-18 Projected annual maximum temperature for Pursat (2020-2050)

8.3.2. Threat profile Pursat Province

The Pursat Province threat profile is given below:

Summarized data up to 2050:

Variable	Dry season			Wet season		
	Baseline	2050	Changes	Baseline	2050	Changes
Maximum temperature	29.9 °C	32.1 °C	2.2 °C	28 °C	31 °C	3 °C
Precipitation	279 mm	278 mm	-0.4 %	1267 mm	1363 mm	7.5 %

Potential threats from projected climate change by 2050:

- Significantly hotter and wetter in the wet season
- Significantly hotter and slightly dryer in the dry season

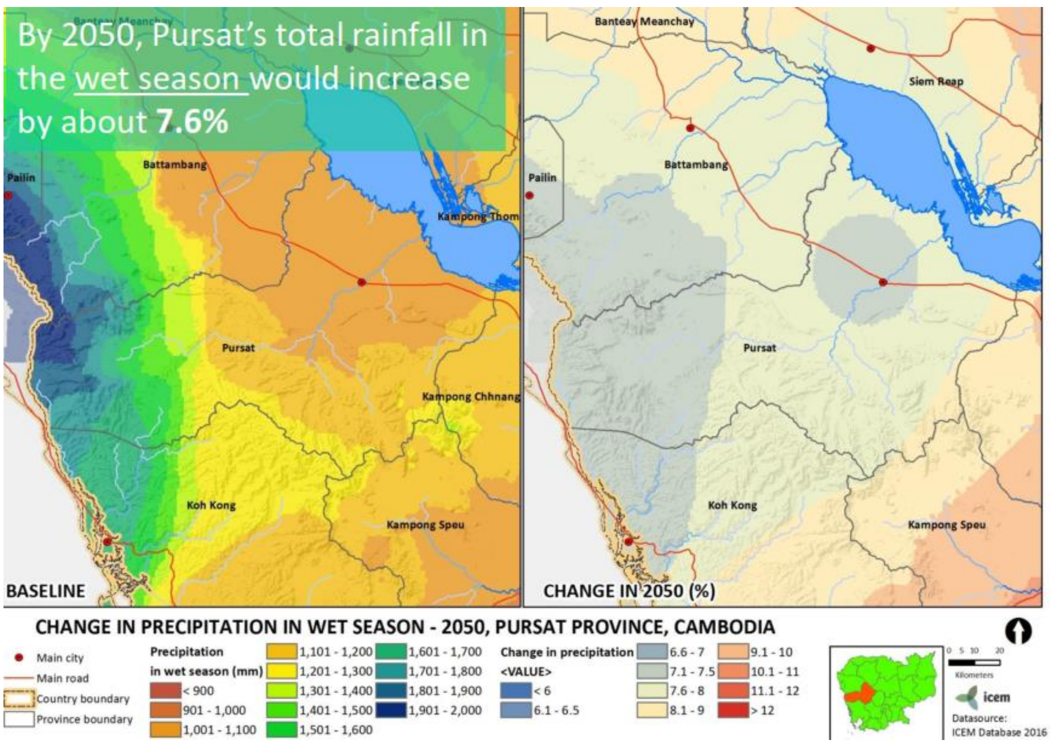


Figure 8-19 Changes in Rain fall in Wet Season

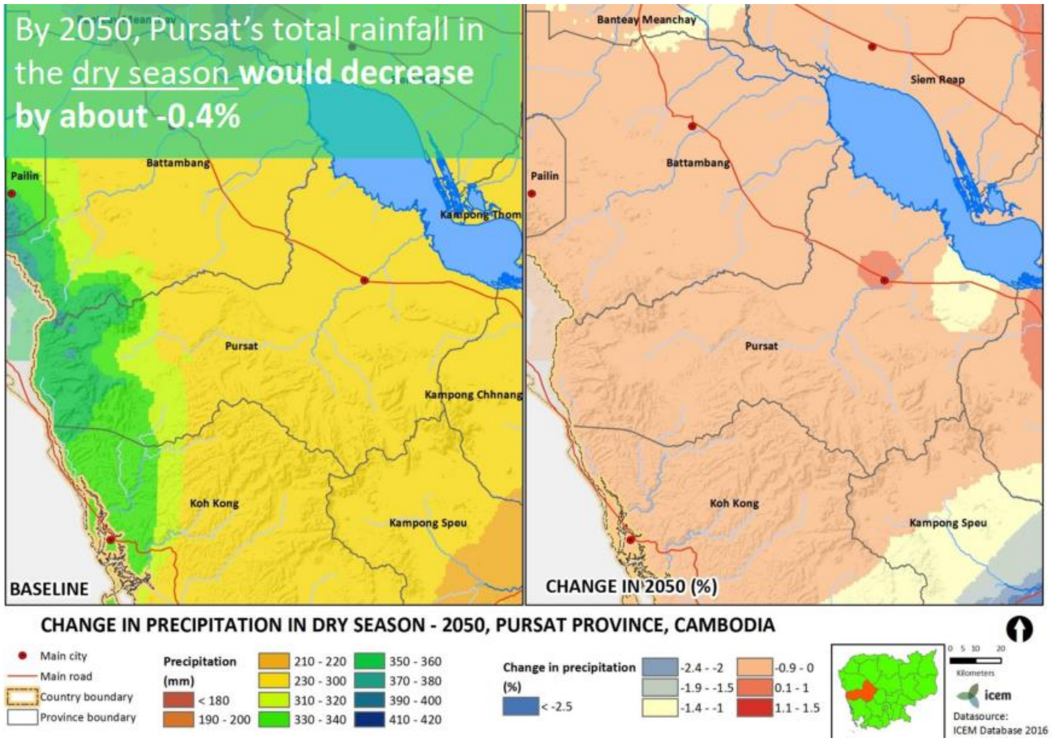


Figure 8-20 Changes in Rain fall in Dry Season

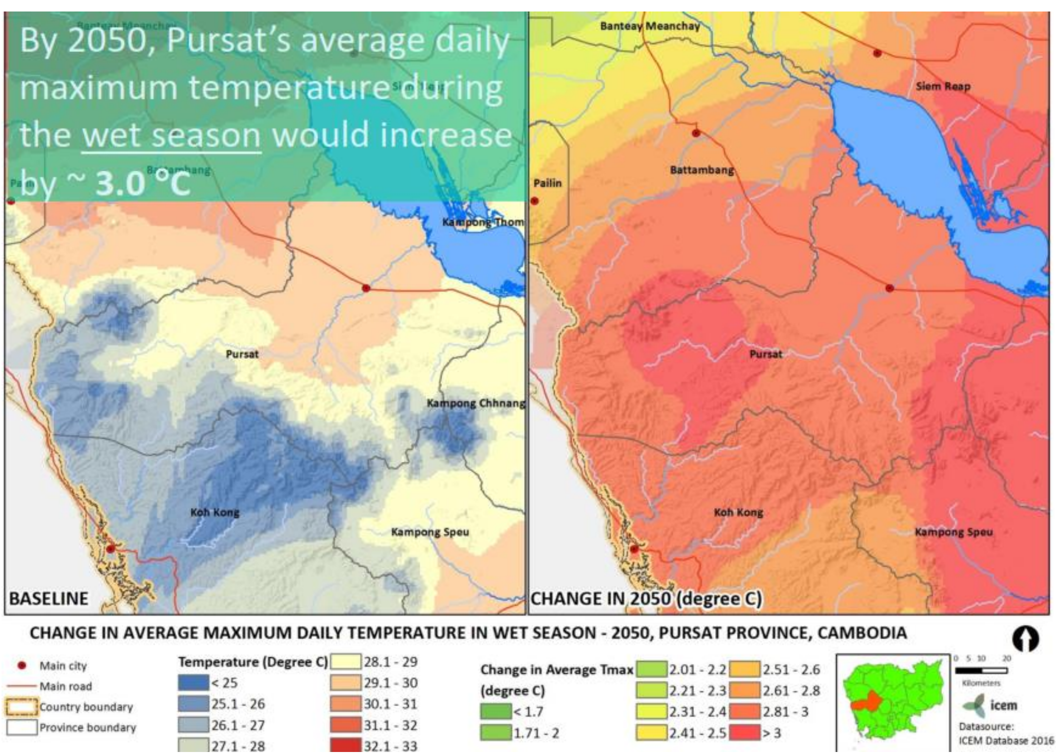


Figure 8-21 Changes in Temperatures in Wet Season

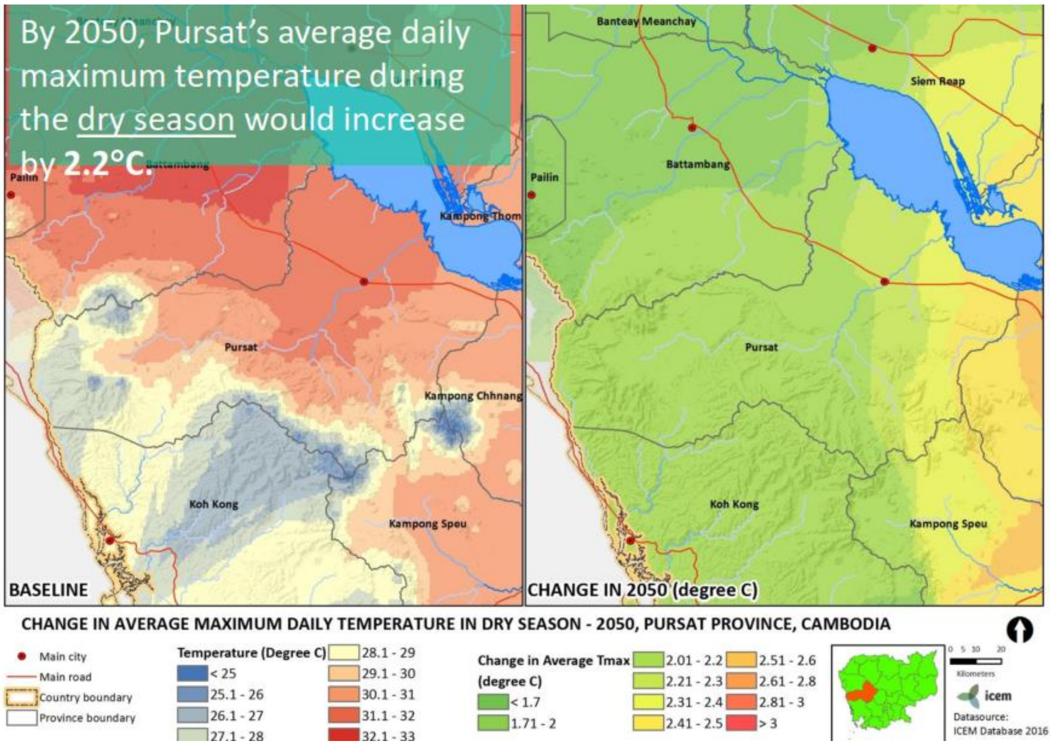


Figure 8-22 Changes in Temperatures in Dry Season

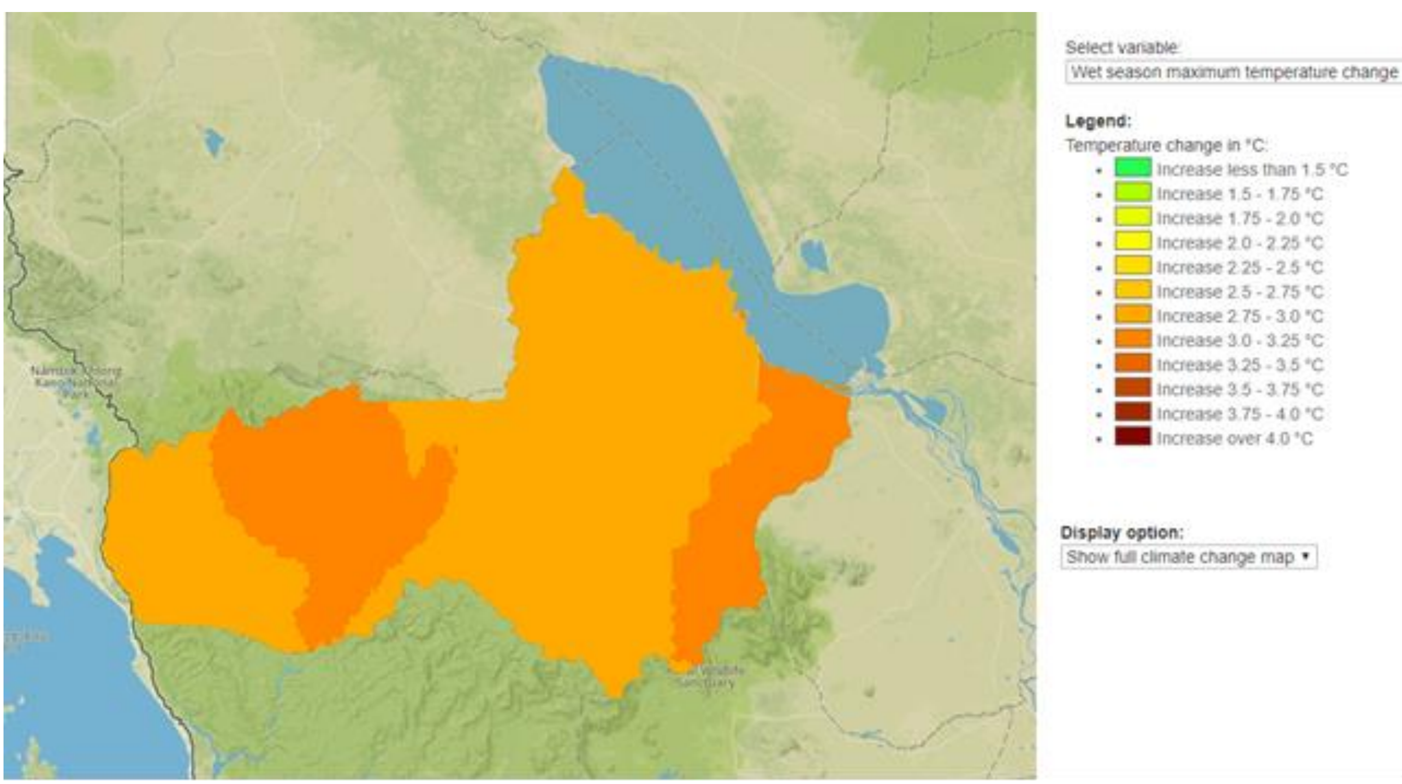


Figure 8-23 Wet Season Maximum Temperature Change

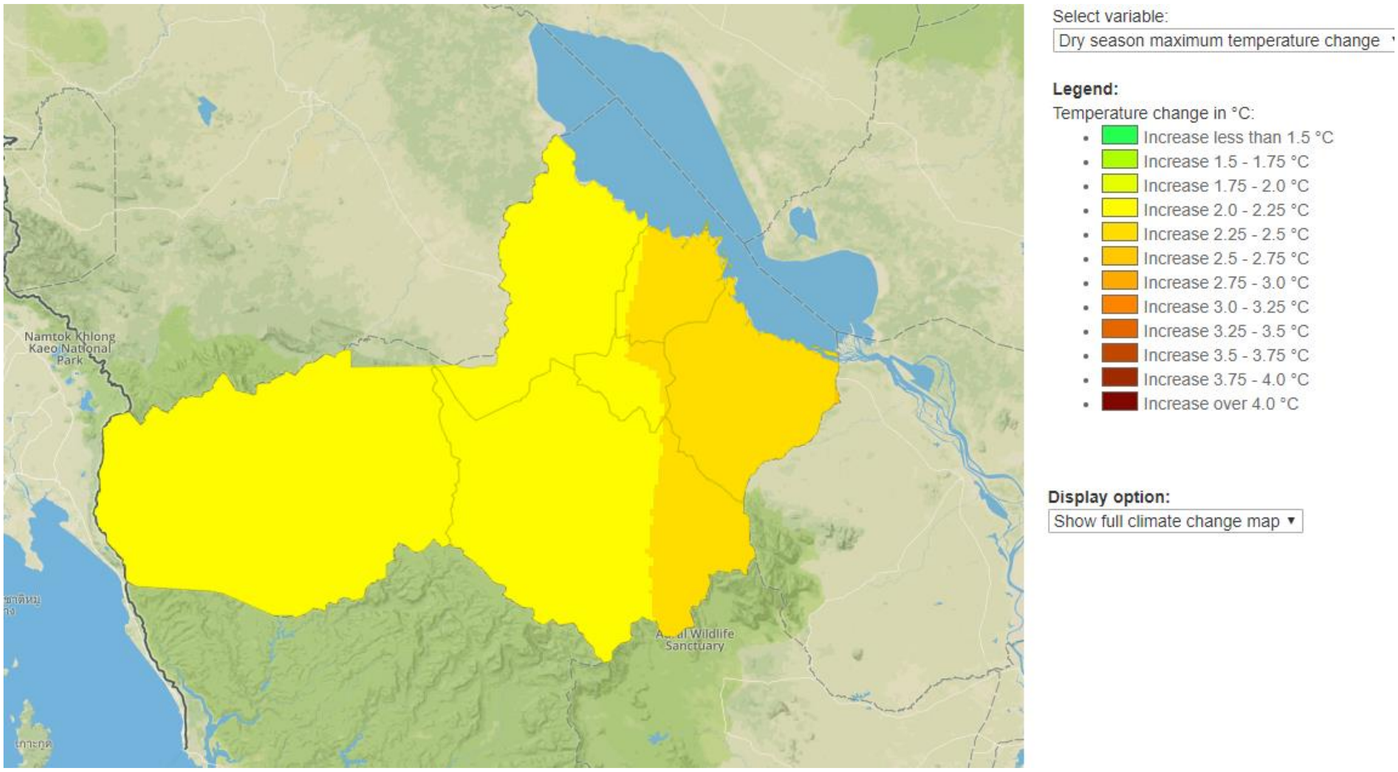


Figure 8-24 Dry Season Maximum Temperature Change

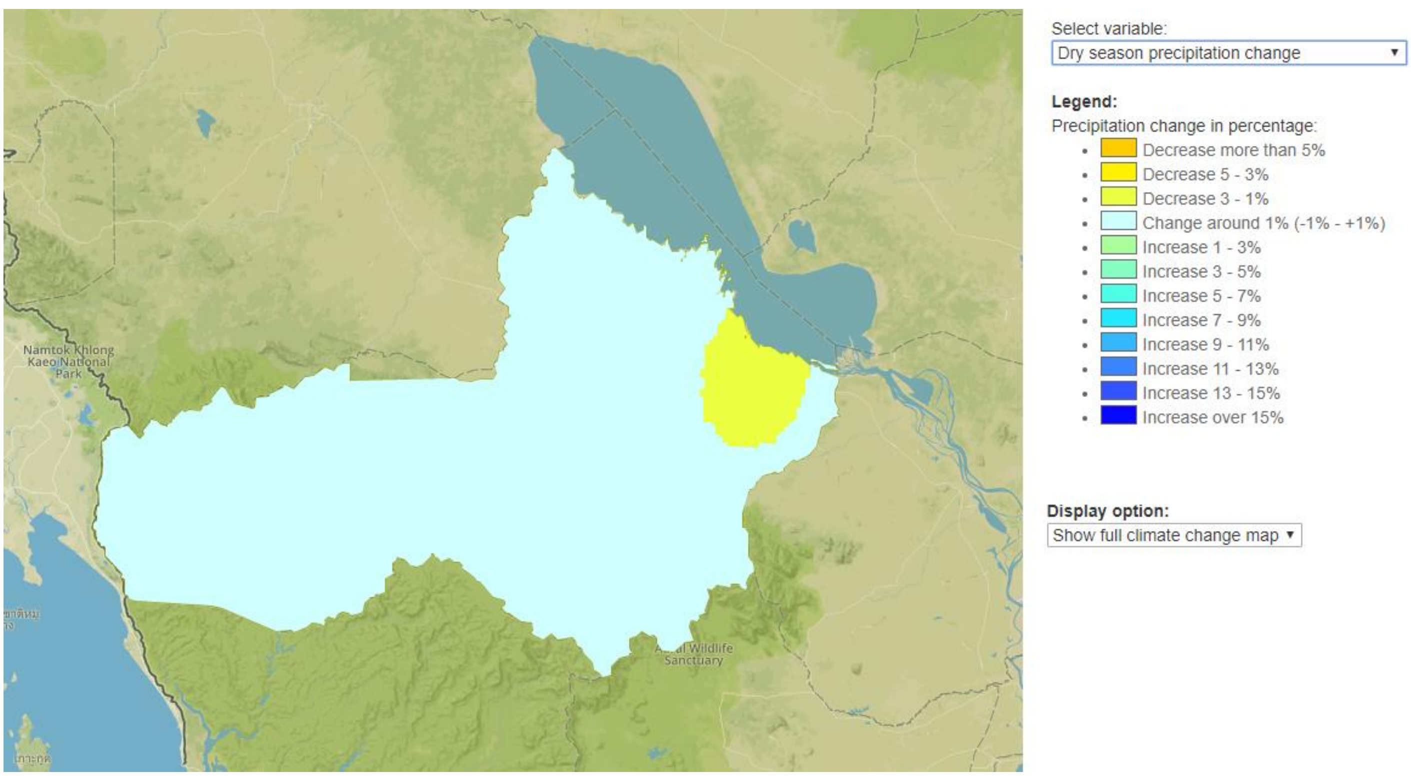


Figure 8-25 Dry Season Precipitation Change

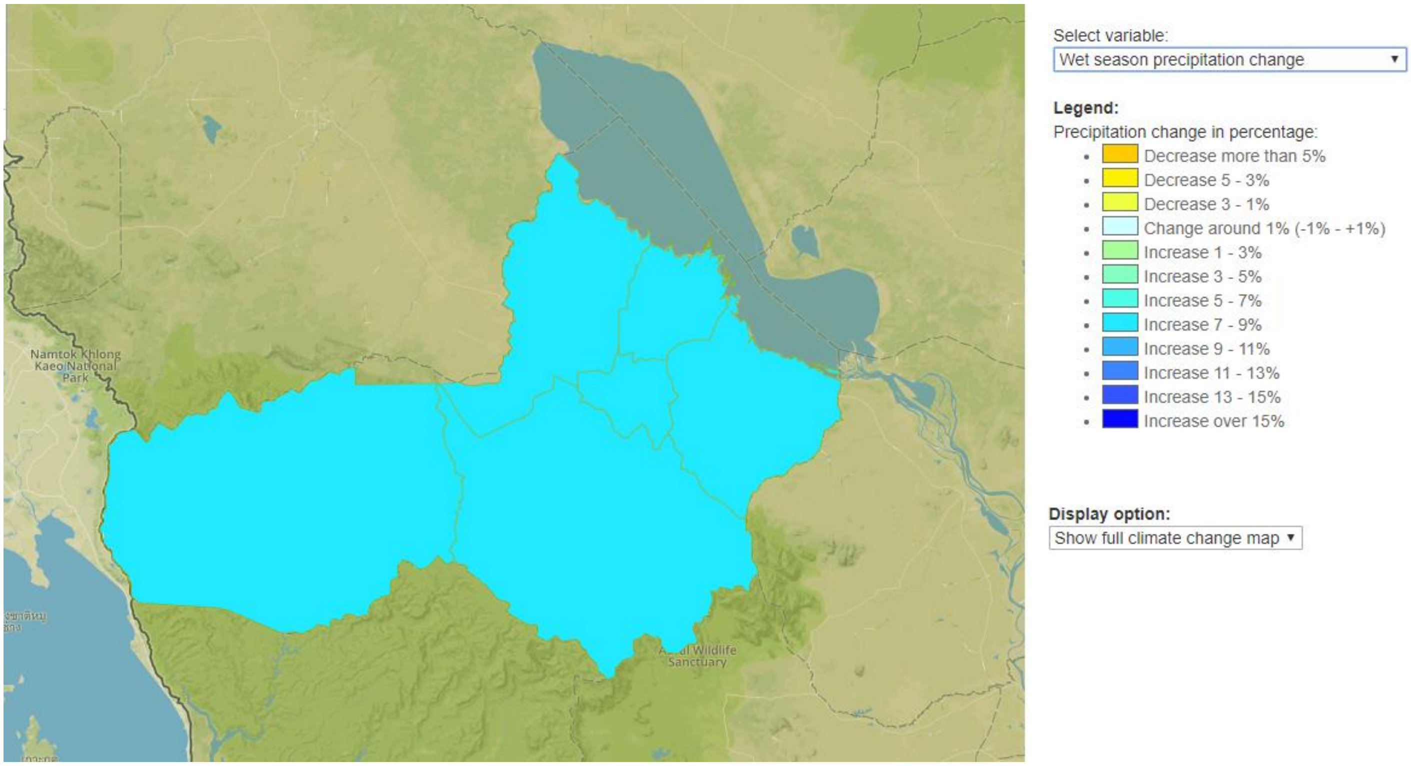


Figure 8-26 Wet Season Precipitation Change

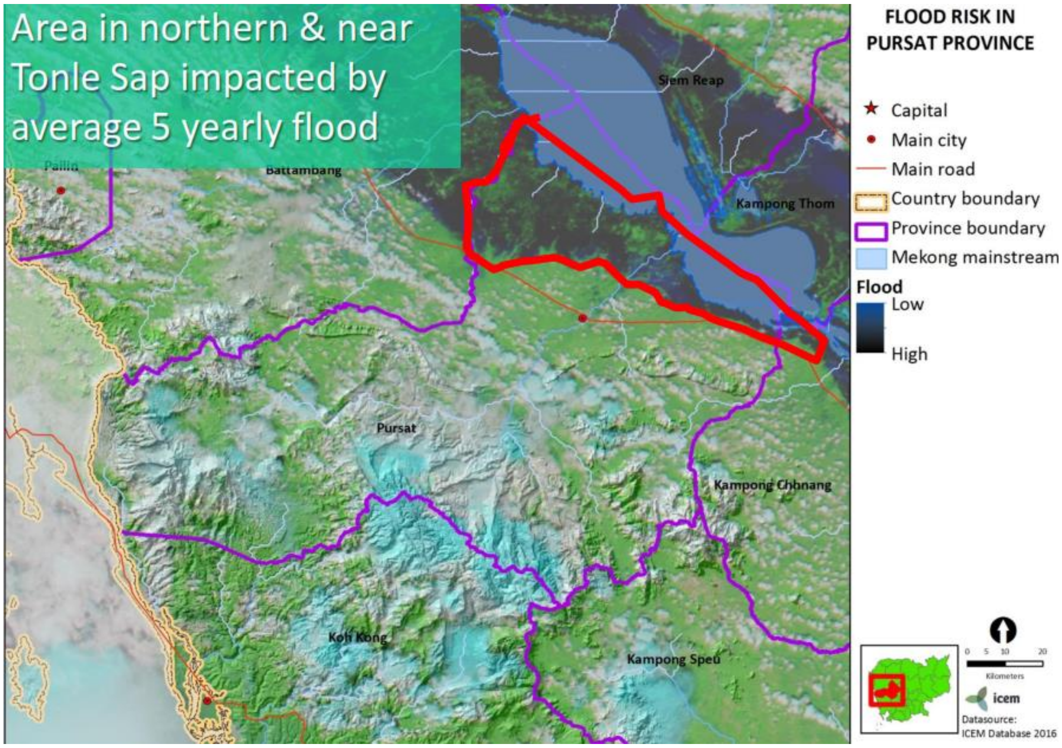


Figure 8-27 Changes in Floods with Climate Change

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

8.3.3. FRMI Climate Change Risks

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

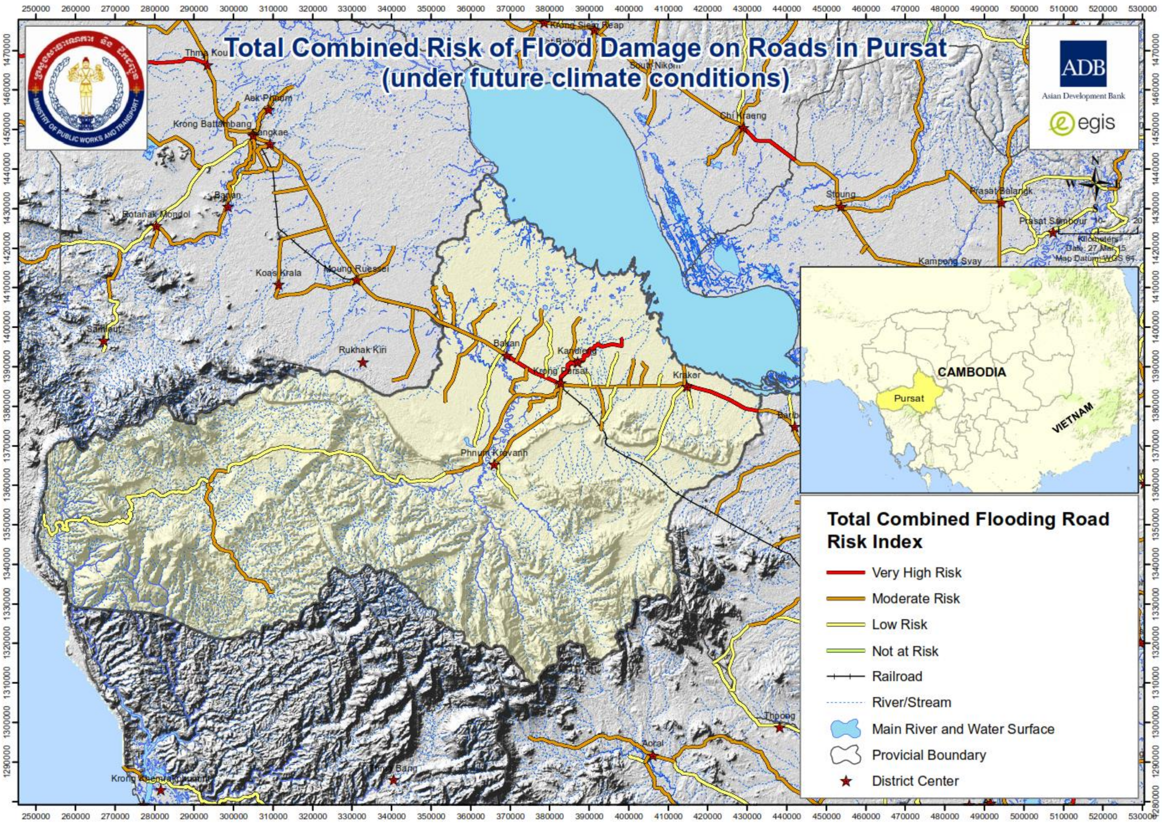


Figure 8-28 FRMI Flood Risk Map Pursat Province

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

9. Approach to Climate Change in Detailed Design

9.1. Comparison of Climate Change Projections

123. 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 9-1 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

124. 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.

9.2. Rainfall

125. Knowing what rainfall intensity and duration figures apply is absolutely fundamental in any access road design. This applies not only to the drainage but also to the elevation of the wearing course above any likely flood levels. (This is known as freeboard.)

126. The IDF values given below were used in the design. This is based on Pursat which is typical of towns around the Tonle Sap basin.

Table 9-2 IDF Values Pursat

Pursat Rainfall Intensity (mm/hr)						
Time	Frequency – Average Recurrence Interval					
(hours)	2 years	5 years	10 year	20 years	50 years	100 years
0.5	44	54	70	88	115	138
1	29	34	43	54	69	81
3	14	17	20	24	30	35
6	9.2	11	13	15	18	20
12	6.0	6.7	7.8	9.1	11	12
18	4.6	5.1	5.9	6.8	7.9	8.7
24	3.9	4.3	4.9	5.5	6.3	7.0

48	2.5	2.7	3.0	3.4	3.8	4.1
72	2.0	2.1	2.3	2.5	2.8	3.0

The MPWT Cambodia Road Design Manual uses IDF curves for the design of storm water canals, pipes and culverts. These are available for Battambang which is 100kms northwest of Pursat. As it has a very similar climate and rainfall pattern, data from Battambang can be used as an indicative guideline for Pursat.

127. The IDF curves for Battambang are shown in Figure 9-1 below.[5]

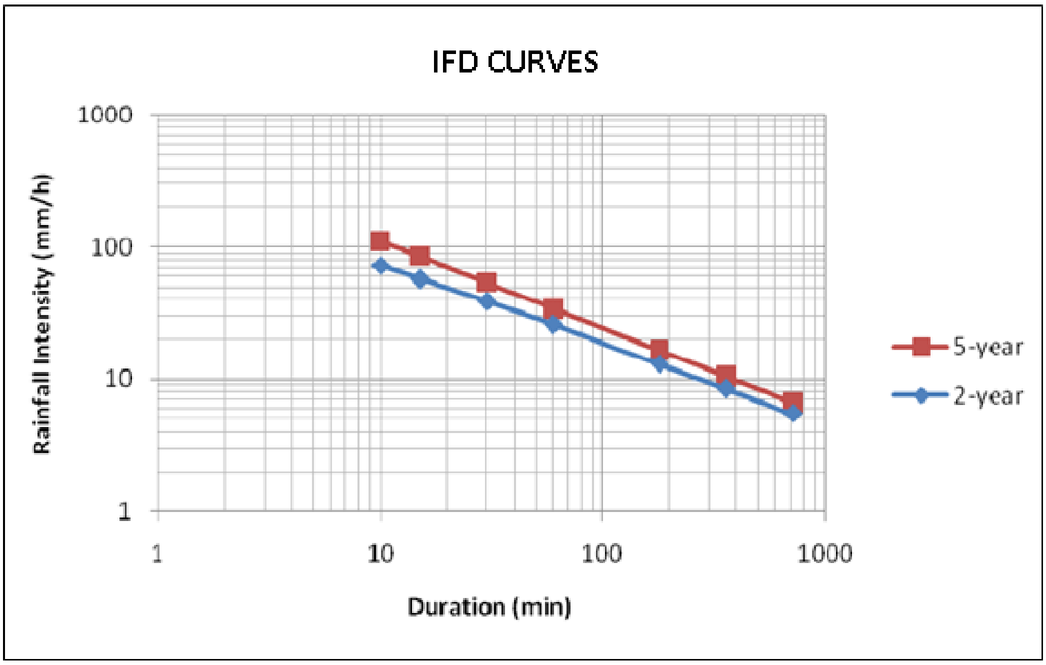


Figure 9-1 IDF Curve for Battambang as a Proxy for Pursat

9.3. Projections of Annual Precipitation

128. The overall conclusion is that annual precipitation in the project area will rise slowly, if at all.

9.4. Monthly Increase during Flood Period

129. The main change in rainfall will occur in the three wettest months of the year, August to September. 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.

[5] : Royal Government of Cambodia. MPWT Road Design Manual 2010

9.5. Storm Projections

130. A paper by O'Gorman in Nature Geoscience Letters[6] 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.

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

9.6. Overview of Precipitation Changes

132. 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 9-3 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

133. 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 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°C. This factor is conservative and is recommended as a design factor.

9.7. Adaptation Measures

134. 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 9-4 Climate Change Adaptation Measures

Civil Works

- Increased height of access road above flood levels
- Raise embankment boundaries

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

- 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.

9.8. Specific Recommendations from MPWT

135. 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 1.3 Literature Review.)

9.9. Field Work and Ground Truthing

136. 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.

9.10. Elevation

137. 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.

9.11. Flood Calculations

138. 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.

9.12. Embankments

139. 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.

9.13. Drainage Design

140. 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.

9.14. Maintenance

141. 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.

142. 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.

10. Incremental Climate Change Costs of TLS1

The project is still evolving and estimating the additional incremental cost of designs resulting from climate change is not simplistic. The design team have access to the data from the MRC Initial Studies Project (ISP) to assess Existing, Future and Residual Flood Risks in three Flood Focal Areas of the Lower Mekong Basin which is some cases results in a decrease of costs.

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 will need to be addressed by the detailed design consultants at some point in the future.

11. Conclusions

143. The Tonle Sap Basin has an Urban Development Framework which guides climate resilient infrastructure development. Pursat and Kampong Chhnang each have their own Urban Development Strategies.

144. Both Kampong Chhnang and Pursat government agencies listed poor environmental sanitation as a serious infrastructure issue.

145. Pursat municipality prioritized town centre flood protection by raising and strengthening the Pursat river embankments with groynes to prevent embankment erosion, and rehabilitating and extending the existing drainage system with more road side drains; and improvement in solid waste management (SWM).

146. Kampong Chhnang municipality prioritized alleviation of annual flooding from the Tonle Sap by raising and upgrading the existing embankment to the North and East of the town. Also improvement of environmental sanitation for the large communities living on and adjacent to the Tonle Sap was deemed a priority.

147. The Integrated Urban Environmental Management in the Tonle Sap Basin Project (IUEMTLSB) which is being implemented by The Ministry of Public Works and Transport will address both these town's priorities under TLS1. (Further issues such as sewage treatment plants will be tackled under TLS2.)

148. 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 11-1 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

149. 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.

150. 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.

151. 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.

152. 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.

153. 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 CRVA.

154. 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.

155. 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.
- ➢ 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.

156. With respect to Time Steps much projected data is given as daily values but for design purposes often hourly or smaller time steps are recorded. IDF curves are available for Battambang. For the purposes of design correction factors obtained by extrapolating downwards the data for Battambang can be adopted.

157. 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.

158. 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.

159. The Tonle Sap Lake 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. It absorbs about 20% of the Mekong River's floodwaters. The Tonle Sap is connected to the Mekong River by the Tonle Sap River, which reverses its flow seasonally. As a result of climate change impacts, 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, and the probability of river floods is likely to increase.

160. The project is still evolving and estimating the additional incremental cost of designs resulting from climate change is not simplistic. The design team have access to the data from the MRC Initial Studies Project (ISP) to assess Existing, Future and Residual Flood Risks in three Flood Focal Areas of the Lower Mekong Basin which is some cases results in a decrease of costs. These issues will need to be addressed by the detailed design consultants at some point in the future.

12. Annex A Works Schedule

Figure 12-1 Project Implementation Plan for IUEMTBP

Note: SID and BD prep-and/or extension construction season-1Q 2020

Item	2015	2016	2017	2018	2019	2020	2021	2022
1. Kampong Chhnang Urban Area Environmental Improvements								
1.1 Improved Reinforced and Raised River Embankment (rev.-fwd/extend-1Q)								
Conduct topographical and soil surveys								
Update feasibility study and prepare appraisal report for ADB and government approval								
Issue ICB bids, evaluate bids and submit to ADB for no objection								
Submit external resettlement M & E report to ADB (continuous, as per agreed RPs)								
Award contract and construct embankment from section O to A, and C to D (Possible during higher lake levels)								
Transfer of O & M responsibilities for drainage and flood control systems to urban service unit (USU)								
Dry season 1: Construct embankment from section A to C								
Dry season 2: Construct embankment from section D to I								
Contract embankment from section I to M (Possible during higher lake levels)								
Road surfacing and supervision intermittent								
Final handover of works								
Internal monitoring of safeguards, including RPs and EMPs (continuous, as per agreed safeguard documents)								
Defects liability period								
1.2 Improved Solid Waste Management								
Conduct topographical and soil surveys								
Update feasibility study and prepare appraisal report for ADB and government approval								
Transfer of O & M responsibilities and tariff collection for solid waste management to USU								
Issue bids, evaluate bid and submit to ADB for no objection								
Submit external resettlement M & E report to ADB (continuous, as per agreed RPs)								
Award contract for landfill construction								
Procure Landfill Equipment								
Remediation of old dumpsite at Traok								
Landfill Construction & supervision								
Procure collection Equipment								
Final handover of works								
Internal monitoring of safeguards, including RPs and EMPs (continuous, as per agreed safeguard documents)								
Defects liability period								

Detailed Component Implementation Plan (revised-at Inception Phase-Feb2017)-Source-Table 3: PAM

Activity	2015	2016	2017	2018	2019	2020
2. Pursat Urban Area Environmental Improvements	2021	2022				
2.1. Improved Town Centre Drainage						
Conduct topographical and soil surveys						
Update feasibility study and prepare appraisal report for ADB and government approval (2sets: one for drainage [ICB])						
Issue ICB bids, evaluate bids and submit to ADB for no objection (drainage)						
Submit external resettlement M & E report to ADB (continuous, as per agreed RPs)						
Award contract to drainage works						
Transfer of O & M responsibilities for drainage to USU						
Construct drainage system starting at foot of system, construct pumping stations and WWTP with road rehabilitation as required						
Supervise start-up and commissioning of WWTP						
Final handover of works						
Internal monitoring of safeguards, including RPs and EMPs (continuous, as per agreed safeguard documents)						
Defects liability period						
2.2. Riverbank Erosion Protection						
Conduct topographical and soil surveys						
Update feasibility study and prepare appraisal report for ADB and government approval (one set for riverbank protection [NCB])						
Issue ICB Bids, evaluate bids and submit to ADB for no objection (drainage)						
Submit external resettlement M & E report to ADB (continuous, as per agreed RPs)						
Award contract for riverbank erosion protection						
Construction of riverbank protection						
Final handover of works						
Internal monitoring of safeguards, including RPs and EMPs (continuous, as per agreed safeguard documents)						
Defects liability period						
2.3. Improved Solid Waste Management						
Conduct topographical and soil surveys						
Update feasibility study and prepare appraisal report for ADB and government approval						
Transfer of O & M responsibilities and tariff collection for solid waste management to USU						
Issue bids, evaluate bid and submit to ADB for no objection						
Submit external resettlement M & E report to ADB (continuous, as per agreed RPs)						