Climate Risk and Vulnerability Assessment

Project Number: 53199-001
October 2021

Cambodia: Livable Cities Investment Project

Bavet

ABBREVIATIONS

ADB	–	Asian Development Bank
ASL	–	Above Sea Level
AUSAID	–	Australian Agency for International Development now called Australian Aid
CC	–	Climate Change
CCCSP	–	Cambodia Climate Change Strategic Plan
CMIP	–	Climate Model Intercomparison Project
CRAA	–	Climate Risk and Adaptation Assessment
CSIRO	–	Commonwealth Scientific and Industrial Research Organisation
DRR	–	Disaster Risk Reduction
GCM	–	Global Climate Model
GHG	–	Greenhouse Gas
GIS	–	Geographic Information System
GMS1	–	Greater Mekong Subregion Southern Economic Corridor Towns Development Project
LCIP	–	Livable Cities Investment Project
LFG	–	landfill gas
MoE	–	Ministry of Environment
MA	–	municipal administration
MPWT	–	Ministry of Public Works and Transport
NAPA	–	National Adaptation Program of Action to Climate Change
NCDM	–	National Committee for Disaster Management
NCSD	–	National Council for Sustainable Development
RCP	–	Representative Concentration Pathway
SDGs	–	Sustainable Development Goals
SRES	–	Special Report on Emissions Scenarios
SST	–	Sea Surface Temperatures
SWM	–	Solid Waste Management
UNDP	–	United Nations Development Programme
UNDRR	–	United Nations Office for Disaster Risk Reduction
WWTP	–	Wastewater Treatment Plant

GLOSSARY

Adaptation	–	The process of adjustment to actual or expected climate and its effects in order to either lessen or avoid harm or exploit beneficial opportunities (IPCC 2014).
Adaptive Capacity	–	The general ability of institutions, systems, and individuals to adjust to potential damage, to take advantage of opportunities, or to cope with the consequences of climate change impacts. (Millennium Ecosystem Assessment).
CMIP Climate Model Intercomparison Project		An ensemble of global climate models used to generate projections of future climate conditions as part of the IPCC climate change Assessment Reports. CMIP5 models uses RCPs to represent CO_2 changes in the future, whereas CMIP3 uses SRES scenarios
Exposure		The nature and degree to which a system is exposed to significant climate variations here it describes the mapped extent of climate change impacts such as areas subject to flooding or storm surge.
IPCC		Intergovernmental Panel on Climate Change
Resilience	–	A measure of the current ability of a community to resist, absorb, and recover from the effects of hazards, by quickly preserving or restoring essential basic structures and functions.
Sensitivity		A measure of the degree to which a system is directly or indirectly affected by a particular climate stimulus
SRES Special Report on Emissions Scenarios CO_2 scenarios		A pathway of greenhouse gas emissions that leads to a particular concentration by the year 2100 adopted by the Intergovernmental Panel on Climate Change for its third assessment report (IPCC 2000). There are four emission scenarios based on future demographic, politico-societal, economic, and technological storylines. The scenarios used here are; SRES A2 considered to be a high CO_2 scenario where emissions are projected to continue to rise throughout the 21st century due to high population growth with slow technological change. SRES B2 a low emission scenario due low population growth and the introduction of clean and resource-efficient technologies.
RCP Representative concentration pathway		A pathway of greenhouse gas emissions that leads to a particular concentration by the year 2100 adopted by the Intergovernmental Panel on Climate Change for its fifth assessment report (IPCC 2014). There are four pathways, expressed as the amount of extra radiative forcing in Wm^{-2} in 2100 produced by greenhouse gases: Under RCP4.5, emissions are assumed to peak around 2040, then decline. Under RCP8.5, emissions are projected to continue to rise throughout the 21st century.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

1. Cambodia's climate is tropical monsoon characterized by a rainy season which accounts for 90% of annual precipitation from May to early October with hot south-west monsoon winds and a dry season, from November to April with cooler north-east winds. The remnants of tropical typhoons crossing Vietnam from the Western Pacific result in tropical depression crossing Cambodia from east to west producing extreme rainfall events that result in widespread flooding. Conversely the heat intensity during the dry season causes water shortages and widespread drought.

2. The Intergovernmental Panel on Climate Change (IPCC) has concluded that global warming will cause sea level rise and significant climate changes throughout the world. The pattern of sea surface temperatures (SST) influences the distribution of rainfall (and typhoons) in the tropics. Climate change is projected to lead to increases in SST resulting in periods of more intense rainfall, increasing the impacts of flash floods and landslides. Higher air temperatures will also impact water supply by increasing losses of surface and ground water through increased evapotranspiration which, coupled with more variability in rainfall, will potentially lead to greater water deficits in water supply catchments during droughts.

3. Being one of the most vulnerable countries to climate change, Cambodia has been one of the climate pioneers in Southeast Asia. Cambodia has been a Party to the United Nations Framework Convention on Climate Change (UNFCCC) since the ratification in December 1995 and ratified the Kyoto Protocol in 2002.

4. The Cambodia Climate Change Office (CCCO) established in 2003 and upgraded to the National Climate Change Committee (NCCC) in 2009 was responsible for a wide range of climate change related activities. The Cambodia Climate Change Strategic Plan for 2014 – 2023 and the supporting Climate Change Action Plan for 2016-2018 were developed as the first comprehensive policy document to respond to climate change issues to advance the development towards low carbon, resilient, equitable and sustainable society.

5. In 2015, the Royal Government of Cambodia recognized the importance of environmental protection and climate change in economic development efforts and that many environmental issues are cross-sectoral. Therefore, the National Council for Sustainable Development (NCSD) became the major mechanism for coordination of climate change response, improving coordination amongst government agencies, at both national and sub-national levels, and cooperation with all the stakeholders. The NCSD developed the Rectangular Strategy for Growth, Employment, Equity and Efficiency: Building the Foundation Toward Realizing the Cambodia Vision 2050 Phase IV (2018) that incorporates adaptation and vulnerability reduction into overarching strategies.

6. Some of the key challenges to effective policy implementation are lack of involvement of key stakeholders, a communication disconnect at all levels, limited technical capacity and finances and the absence of functional implementation structures.

7. At the request of the Kingdom of Cambodia, the Asian Development Bank (ADB) is developing the Livable Cities Investment Project (LCIP) to facilitate long-term sustainable and economic growth. The project is aligned with the Government's policies and national strategies, in particular, the Government's Rectangular Strategy – Phase IV and ADB Strategy 2030.

8. The project is designed to facilitate long-term sustainable and economic growth in the secondary cities of Bavet, Poipet and Kampot by developing strategies to improve urban infrastructure with a focus on sanitation, solid waste management and stormwater drainage sectors. Based on Urban Development Scenario reports, Sector Master Plans identified infrastructure required to meet the future urban needs of the participating cities. Proposed infrastructure is set out for three planning stages; Short-Term (2020-2025), Medium-Term (2025-2030), and Long-Term (2030-2040) as outlined below.

9. The proposed infrastructure for Bavet for implementation in the Short-Term (2020-2025) includes

(i) Wastewater: (a) Wastewater treatment plant for the initially connected population, with some provision for extensions for the longer term; (b) pumping stations to create a transfer chain to the WWTP when areas to be serviced requires, and gravity flows cannot be achieved because of distance and topography, and; (c) the construction of sewer pipes designed primarily for the selected existing built-up areas with some capacity for extensions for future growth.

(ii) Stormwater: Improved drainage pipes and channels along and under the streets in the central commercial area of Bavet integrated with the drainage construction along the national highway including street catch basins, manholes, pipes, and channels on north-south streets.

(iii) Solid Waste Management: (a) Improvement of the existing door-to-door collection system in the urban area; (b) Centralized collection points in rural Sangkat; (c) Conversion of the current dumpsite into a transfer station; (d) New landfill site; (e) Pre-sorting plant and a composting plant, and: (f) Training on O&M contract management, landfilling / Composting / pre-sorting technical management.

10. For the medium term (2025-2030) it is proposed that master plans are reviewed and updated. It is expected that medium term infrastructure will include:

(i) Wastewater: (a) Staged extension of the network, gravity sewers, pumping stations, and force mains to follow the urban expansion: (b) Improvements to the provision of household plumbing and on-site containment and treatment in Rural Areas

(ii) Storm Water: Drainage designed and constructed to service continued urban growth and provide drainage to the Chipu area.

(iii) Solid Waste Management: Extensions to the Landfill and Composting sites.

11. For the long term (2030-2040) it is proposed that master plans are again reviewed and updated to integrate the latest urban settlement and the current urban development, as well as

reviewing the performance of drainage infrastructure, and incorporating updated climate projections.

12. The design period for infrastructure is laid out for three planning stages, however, this feasibility report presents an assessment of the proposed infrastructure that is proposed for the short term, i.e. the next 5 years. As the planning has been carried out for the period to 2040, this Climate Change and Adaptation Assessment (CCAA) presents an assessment of the potential impact of climate change on the project infrastructure by 2040.

13. Data on climate projections that are available from previous reports are presented for various time periods. Where possible ancillary information or interpolation was used to determine climate change projections for 2040. However, if there was insufficient information available to make an interpolation, then the projected parameter values for 2050 or 2055 were used to assess vulnerability.

14. Bavet is located on the eastern border of Svey Rieng on the upper reaches of the Mekong Delta. The region consists generally of the typical plain wet area of Cambodia, with rice fields and other agricultural plantations. Agricultural land use represents the biggest portion of the city.

15. Mean average temperature ranges from 22° to 28°C. Maximum temperatures above 32°C are common before the start of the rainy season and may rise to more than 38°C. Climate change models project an increase in temperature across Cambodia in the future with the average annual temperature for Bavet projected to increase by 0.5 °C by 2030, by 1.3 °C by 2050 and by 3.1°C by the end of the century. Temperature changes are projected to be greater at the start of the dry season and least at the later part of the wet season.

16. The number of hot days (days above 35°C) in the region around Bavet is projected to change from 0-2 to 7-9 by 2060.

17. The projected change in rainfall from climate models is much more variable than it is for temperature. The average projection for annual rainfall from the global climate models (GCM) used in this study is for little change into the future, (1% - 3%). With regards to the range of outputs, some models project a decrease, -4% by 2030, -5% for 2050 and -14% for 2090, while others project an increase of up to 14% by the end of the century. Typhoons and Tropical Storms can bring widespread heavy rainfall and subsequent flooding. It is projected that rainfall events from tropical depressions crossing into Cambodia from typhoons landing in Vietnam will decrease in frequency, but each event will bring more rain. Because Bavet is on the border, extreme rainfall is projected to increase.

18. The very flat terrain of Bavet means that when designing storm water infrastructure, it is difficult to produce enough fall to generate flow in the drains so any increase in the design event size results in extreme increases in the required cross sectional area. Therefore, selection of a large increase in extreme rainfall event size just in case to allow for climate change, risks maladaptation by committing the municipal administration (MA) to large expensive infrastructure

and added costs for relocation. The phased nature of the project means that short term and near term infrastructure planned to be installed in phase 1-2 can be designed to cope with projected climate change in the near term. The long term phase (2030-2040) of the project incorporates revision of the performance of phase 1-2 infrastructure, revision of urban growth and development and importantly revision of any evident trends in rainfall and a reassessment of climate change projections based on the most recent scientific understanding.

19. Studies of recent rainfall has found no statistical trend in the size of extreme rainfall events. However, projections for the increase in cyclone intensity indicates that high rainfall events will increase in the future. Therefore a value of 5% is used for the projected increase in extreme rainfall event size due to climate change, based on the median projection from the results of downscaling from an ensemble of GCMs. Sensitivity analysis carried out during the design of the drainage for Bavet indicated that to cater to an increase in rainfall of 5% would require drains to be 20% larger, with an ever-increasing size needed for higher design rainfalls. Using the median projected increase due to climate change means that it is still economically feasible to develop a climate change proof design based on a 1 in 5 year event. These design parameters result in infrastructure that fits within the envelope of the available space provided by the road reserve and along the existing canal negates the need for households to be relocated and minimized impacts on primary structures.

20. Svay Rieng is downstream of all other weather influences and because of the extremely flat terrain can flood over exceptionally large distances. As a result, widespread flooding from typhoons and other large tropical storm systems occurs across the Province in the wet season. However, the major cause of flooding around Bavet is not due to river flooding. Rather, it is due to no natural drainage combined with inadequate drainage infrastructure that is unable to deal with intense rainfall events exacerbated by obstruction of flows due to poor road design or other anthropogenic activities and interventions. The exposure of Bavet to flood hazard is limited to areas where to superposition of these factors occurs leading to localized flooding.

21. Droughts caused by failure of the monsoon rains are common across Cambodia and extended periods are a large concern. Delays in the onset of monsoon rainfall have significant negative impacts on rice production for subsistence farmers. El Niño events with higher-than-average temperatures and reduced monsoon rains starting later in the season are often correlated with droughts over Southeast Asia and the opposite phase, a La Niña event, is associated with above-normal rainfall and sometimes extreme flood events. An assessment of drought carried out in 2003 by the National Committee for Disaster Management (NCDM) rated the area immediately around Bavet as a low priority in terms of drought. It is projected that there will be no change in the average duration of droughts, a small decrease in the frequency of short 3-month long droughts.

22. Svay Rieng, and Bavet, like much of the rest of the delta, could be exposed to sea level inundation with a rise of 0.8m above current sea level, but this is not projected to occur until the end of the century.

23. A comprehensive social survey on the opinion of specific vulnerable groups on key features related to climate change (flooding/ drought/ hot weather) found that: around a third of participants had experienced localized flooding in the last 10 years that they attributed to inadequate drainage, thought that rainfall had increased and flooding had gotten worse in this time. All participants had been moderately impacted by drought with reduced income from crops or an agricultural business, thought drought periods had become longer in the last 20 years, thought there were more extremely hot days and more consecutive hot days compared to 20 years ago and that hot weather had worsened health issues for members of their household.

24. The review of risks indicates that localized flooding is the most important hazard that will impact Bavet by 2040. Drought will continue to impact Bavet into the future, but the hazards presented to infrastructure are minimal. Heat stress due to high air temperatures may become an additional hazard, particularly if consecutive hot days occur.

25. In regard to future exposure to climate change hazards: exposure to drought will remain the same as at present, exposure to heat stress may increase as maximum temperatures rise and urban heat intensifies. Exposure to flooding is from localized flooding due to problems with drainage and the current extent of the problems are not mapped. Larger rainfall events may increase the depth and extent of the current problems if business as usual is continued.

26. The capacity of the Bavet Municipality to deal with the impacts of extreme events was assessed as medium-low to medium and any impacts to infrastructure that result from flood events will be exacerbated by a limited capacity to respond to the impacts.

27. The risk from climate change to each project component was calculated as the likelihood of a hazard impacting an infrastructure element and the consequences of that impact. Project components are generally rated as Low or Moderate.

28. The largest risks identified in the risk assessment are related to the potential for increased localized flooding due to the projected increase in extreme rainfall events of 5%. Therefore, adaptation measures are related to strategies to decrease these impacts. The major adaptation is a reappraisal of the projected extreme rainfall size used in the design of the drainage infrastructure.

29. Each component of the project contributes to improving the capacity of Bavet to adapt to climate change. Properly treated wastewater, a functioning drainage system and efficient waste management will increase the resilience of the population by improving health and wellbeing, improving the ability of the community to recover from typhoons and other disasters, and will minimize health risks during localized flooding events. Therefore, a proportion of the costs of the installation of the infrastructure are considered to be climate change adaptation. Some components of the project will require specific adaptations to make each element climate change resilient. The proposed adaptation measures and the associated costs are summarized in the Table below.

30. The larger extreme event size means that localized flooding will continue to occur and will increase in extent in areas not serviced by drainage lines. Therefore, the wastewater treatment plant will need to be isolated from the surrounding area that is currently flood prone and will require higher embankments to ensure protection from external flood waters and internal water management designed to manage rainfall events 5% higher than at present.

31. Similarly, the landfill site will also require flood water management designed to manage rainfall events 5% higher than at present.

32. The overall cost of climate change adaptation for the project is calculated as $11.57 million and of that $1.036 million is extra costs associated with specific adaptation strategies.

Table 1: Summary Adaptation Costs

Infrastructure Component	Calculated Risk	Proposed Adaptation Measures	Estimated Adaptation Costs (US)
Wastewater Pumping Stations WWTP	9 Moderate 8 Moderate	1 m added to height of dykes used within the WWTP	8% increase in CAPEX $423,000
		30% of remaining total construction cost (less mitigation costs)	$7,961,922
Stormwater All components	8 Moderate	Increase size of drainage network	11% increase in CAPEX $600,483
		30% of remaining total construction cost	$1,131,806
Solid Waste Landfill	8 Moderate	Increase capacity of stormwater management system	11% increase in CAPEX for drainage $12,999
		30% of remaining Landfill construction costs (less mitigation costs)	$1,438,087

33. The waste management project components, including composting of organic waste; controlled wastewater treatment; GHG capture; recycling and waste minimization are greenhouse gas emission reduction strategies. In particular emissions of the more potent greenhouse gases Methane (CH_4) and Nitrous oxide (N_2O) from anaerobic decomposition will be captured and converted to CO_2. It is expected to cost $1,835,346 to develop a composting plant and $212,943 to install a landfill gas (LFG) collection system and a gas flare unit. Additionally, emissions of CO_2 and pollutants from burning rubbish will also be reduced.

34. The proposed installation of solar PV systems at the wastewater treatment plant and at the solid waste management site will contribute to climate change mitigation and will provide an important demonstration of the use of renewable energy. It is expected to cost $478,500 to install solar panels at the two sites. Additionally, greening of areas where appropriate, provides mitigation through CO_2 sequestration.

Table 2: Summary Mitigation Costs

Infrastructure Component	Proposed Mitigation Measures	Estimated avoided GHG Emissions	Estimated Mitigation Costs (US)
Wastewater	Use of solar power through PV modules	37,353 kg CO_2e/yr	$297,000
Solid Waste	LFG collection and flue	25,811 kg CO_2e/yr	$212,943
	Composting Plant	2,975 – 4,630 kg CO_2e/yr	$1,835,346
Solid Waste	Use of solar power through PV modules	8,398 kg CO_2e/yr	$181,500

35. The Cambodian Government has a number of national strategies to reduce greenhouse gas emissions, and where possible these will be incorporated into the project. The Cambodia Climate Change Strategic Plan (CCCSP) has a strategic objective to promote low-carbon planning and technologies to support sustainable development. General mitigation strategies will be used as part of the overall project strategy where possible such as the use of biofuels, light vehicle technologies, electric vehicles. The project will contribute to mitigation by promoting the use of solar operation at the infrastructure site. The total cost for the proposed mitigations is $2,526,789.

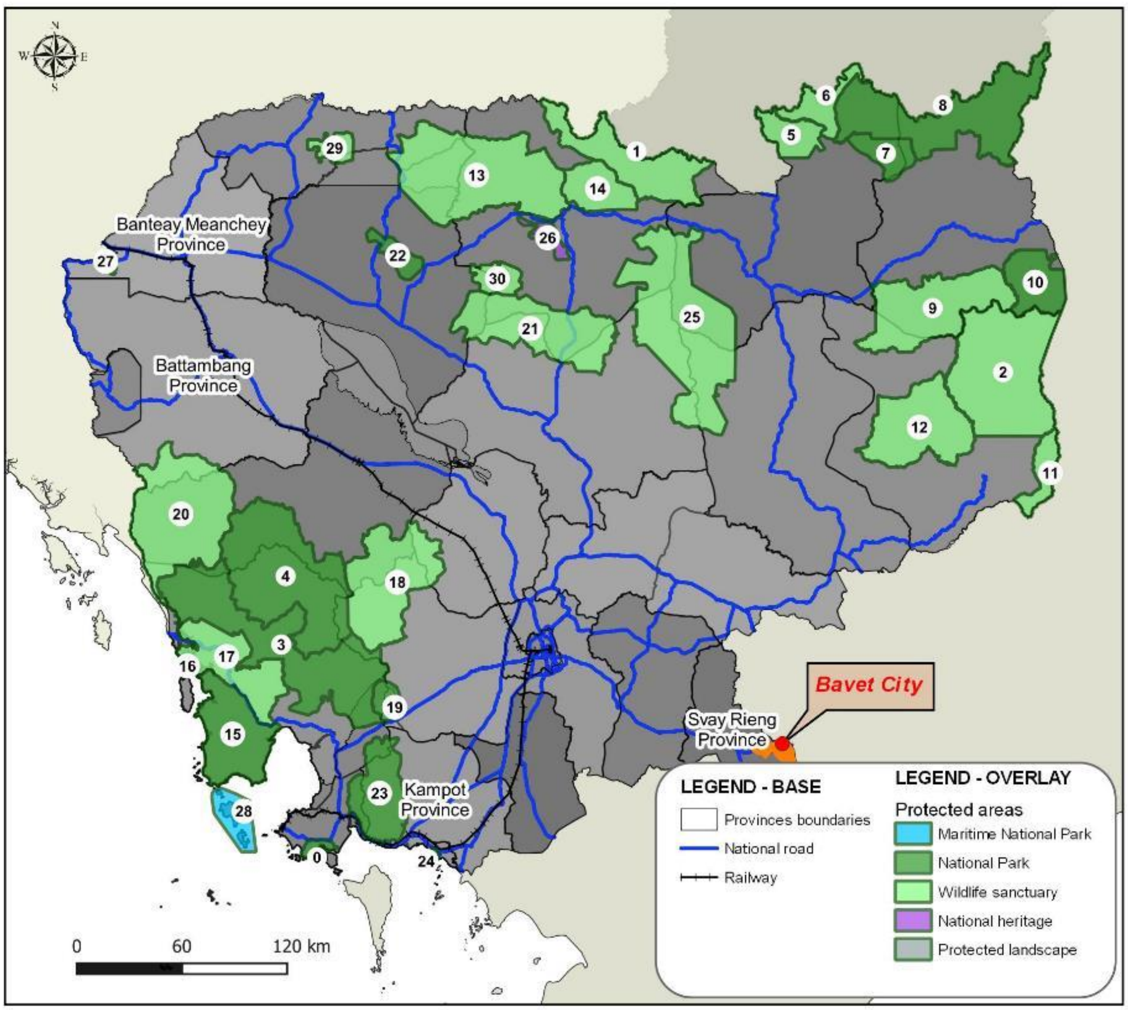
I. INTRODUCTION

1. Study area description

1. Bavet is located on the eastern border of Svey Rieng province and is an international border gate between Cambodia and Vietnam on one of the country's busiest highways, National Highway No 1, which links Phnom Penh and Ho Chi Minh City in Vietnam. Its counterpart across the border is Moc Bai, Vietnam.

2. Svay Rieng province is a small low land province of 2,966 km^2 located in the Southeast of the country that composes a section of land protruding into Vietnam, so the north, south and east of the province is literally surrounded by Vietnam. Prey Veng borders the province to the West. The surrounding region consists generally of the typical plain wet area of Cambodia, with rice fields and other agricultural plantations.

Figure 1: Site Location

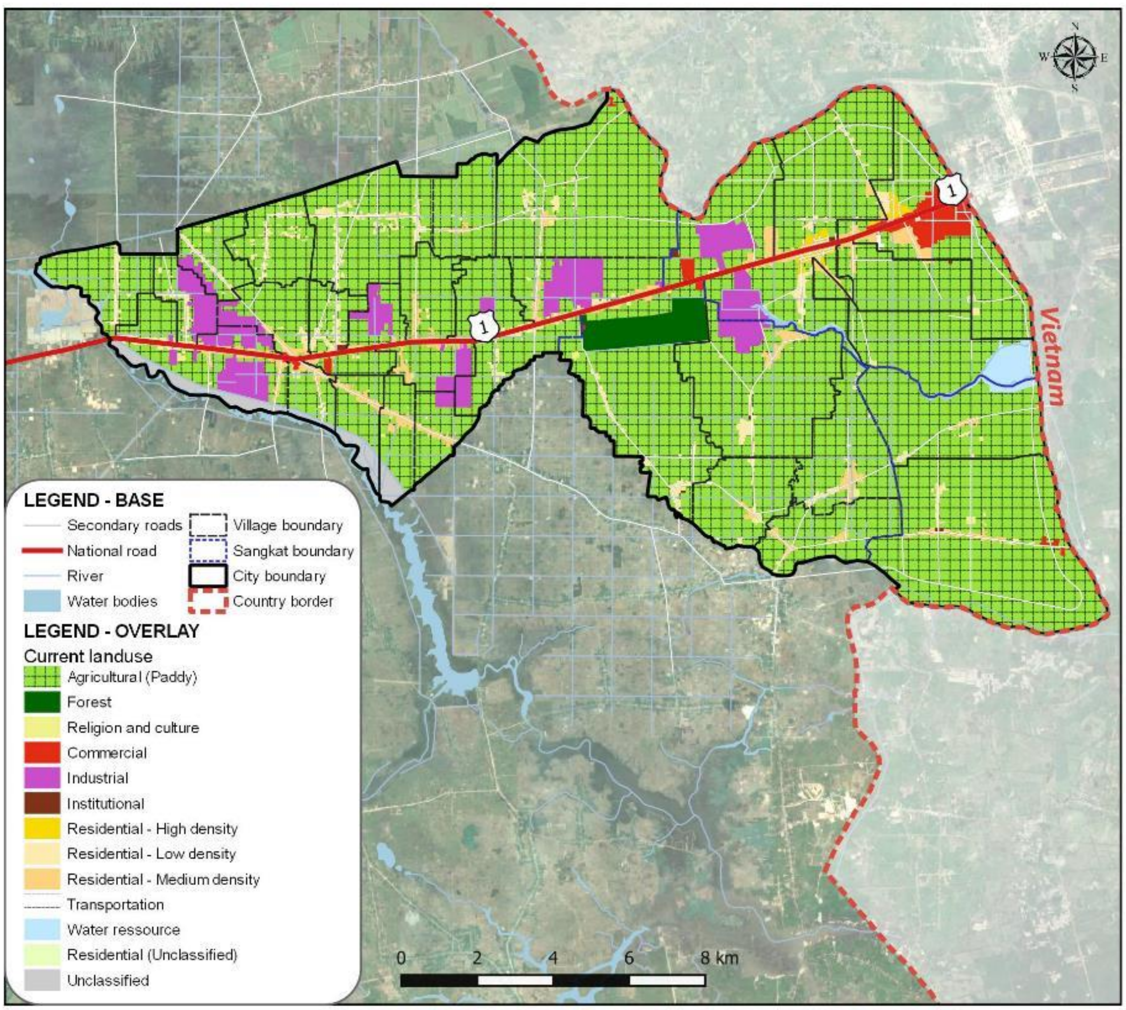


Source: Egis, 2021

3. Svey Rieng is located on the upper reaches of the Mekong Delta and subject to the annual flooding that occurs across the Delta. However, due to natural accumulation of silt across central Svay Rieng over thousands of years of Mekong River flooding, the local drainage of the area around Bavet is now eastwards toward the Vam Co River that drains to the sea south of Ho Chi Minh City. As a result, the area around Bavet is not included in the Mekong River basin as defined by The Mekong River Commission.

4. The city of Bavet was established in December 2008 and is managed by a Municipal Administration (MA). It has a total land area of 206.69 km² made up of 5 Sangkats that are subdivided into Villages (Phum). The administration of each Sangkat is under the supervision of the MA. Agricultural land use represents the biggest portion of Bavet city, 166 km^2 or 37%. There are no extensive natural forests or mountainous areas, but wetlands are common. A small area of forest covering 1% of the total land use is located within the city area.

Figure 2: Current land-use (based on the year 2015)



Source: Egis, 2021

2. Project description

5. At the request of the Kingdom of Cambodia, the Asian Development Bank (ADB) is developing the Livable Cities Investment Project (LCIP) to facilitate long-term sustainable and economic growth. The project is aligned with the Government's policies and national strategies, in particular, the Government's Rectangular Strategy – Phase IV[1] and ADB Strategy 2030.[2]

1 The project will concentrate on the secondary cities of Bavet, Poipet, and Kampot, due to their economic potential and location at key trade and tourism zones. The project will focus on enhancing urban planning, building community resilience, and providing infrastructure. Project outputs include: (i) output 1: policy and regulatory environment improved, (ii) output 2: urban infrastructure improved, and (iii) output 3: institutional effectiveness, and governance improved.

6. As a result of recent population growth, these cities have identified that the limited infrastructure is restricting their development potential. Existing services are no longer operating optimally and incapable of servicing demands. The LCIP proposes to adopt a holistic methodology, comprising of an integrated urban development approach, to ensure interventions consider land use, long term city needs, asset management, and asset financing for sustainable operations.

7. To ensure climate resilient and sustainable development of participating cities, the project adopts a climate-centric city development approach. Appropriate structural and non-structural measures are incorporated to ensure climate change risks is appropriately mitigated to avoid future cost associated to the climate change impact.

8. The project components under output 2 are:

(i) Improved wastewater management systems (pumping stations, network and treatment plant);

(ii) Improved drainage systems to manage stormwater flows, and;

(iii) Improved SWM systems (including landfill, waste collection & recycling, and transportation vehicles, an upgrade of environmental protection measures and activities to promote waste reduction).

9. Following the Urban Development Strategy (UDS), the sector Master plan (MP), and the Comprehensible Technical Options Study (CTOP), the Feasibility Study including this CRVA were completed.[3] The proposed infrastructure for LCIP in Bavet is set out for three planning stages; Short-Term (2020-2025), Medium-Term (2025-2030), and Long-Term (2030-2040) as outlined below.

[1] *Kingdom of Cambodia. 2018. Rectangular Strategy for Growth, Employment, Equity and Efficiency: Building the Foundation Toward Realizing the Cambodia Vision 2050 Phase IV. Phnom Penh.*
[2] ADB. 2018. *Strategy 2030: Achieving a Prosperous, Inclusive, Resilient and Sustainable Asian and the Pacific.* Manila.
[3] Prepared under TA 9554-REG: Southeast Asia Urban Services Facility

2.1. Short term (2020-2025)

10. The proposed infrastructure for Bavet for implementation in the Short-Term (2020-2025) are described below.

Wastewater

11. There is, at present no sewer and no wastewater treatment plant in Bavet. The assessment of the fecal and non-fecal waste disposal chain, both in rural and urban areas, suggests that 74% of fecal waste is not managed safely. Within the town center, wastewater is not being adequately evacuated from urban areas and remains stagnant in urban areas.

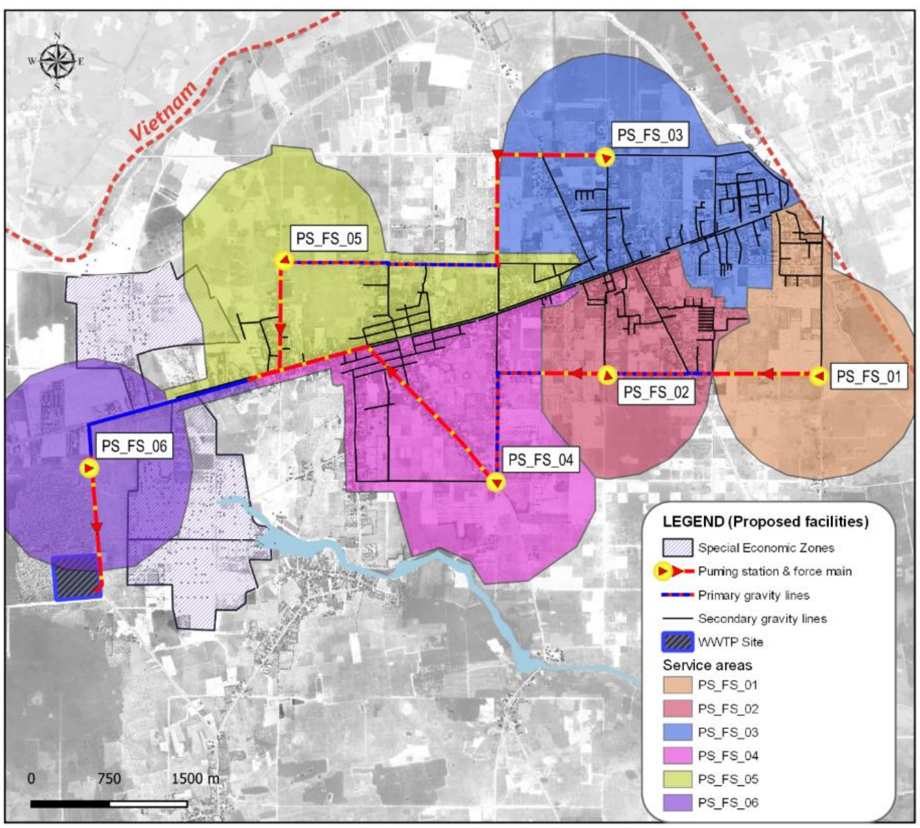
12. Based on the selected scenario for the master plan, a centralized wastewater treatment plant (WWTP) will serve the built-up area of Bavet and its extension in the medium and long term horizon. Under LCIP, providing sewerage and connections to the existing population will be a priority but with the expected capacity required for the long term. It is suggested to start the implementation with:

(i) Construction of a wastewater treatment plant for the initially connected population;

(ii) Construction of pumping stations to create a transfer chain to the WWTP;

(iii) Construction of sewer pipes designed primarily for the selected existing built-up areas with some capacity for extensions for future growth.

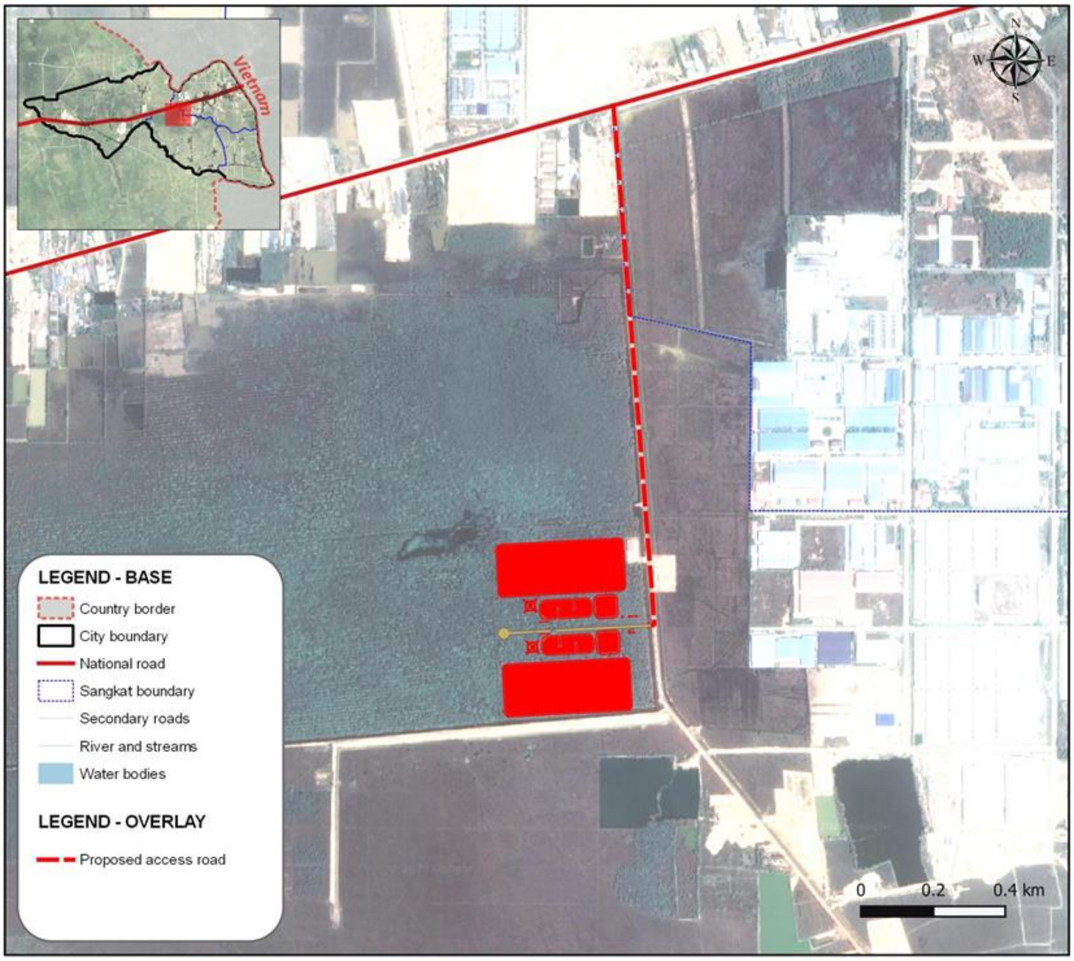
Figure 3: Proposed Service Areas (wastewater)



Source: Egis, 2021

13. The Project focuses on the furniture of sewerage system for the areas delineated by the zoning 2025 (short term area) but provides infrastructure designed for future needs.

Figure 4: WWTP site localization



Source: Egis, 2021

Table 3: Wastewater – Investment Horizon and Design Capacity

Item	LCIP – investment horizon	Design Capacity
Sewer Network	2025 – short term or priority area	2040
Pumping Stations & Force mains		Equipment 2030 Civil works 2040
WWTP		2030

Table 4: Summary Table of Investment in Bavet (wastewater)

Investment Area	Components
Pumping stations	6 PS
Networks	66 km of gravity lines, 9.5 km of force mains
Wastewater Treatment Pant	Waste Stabilization ponds

Stormwater

14. Bavet has more than 20 km of the open channel network. The size of those channels varies between 2 and 4 meters and depth from 1 meter to 3 meters. The open channel network is now considered as the main drainage infrastructure. This network is the outfall of some drainage/sewerage pipes.

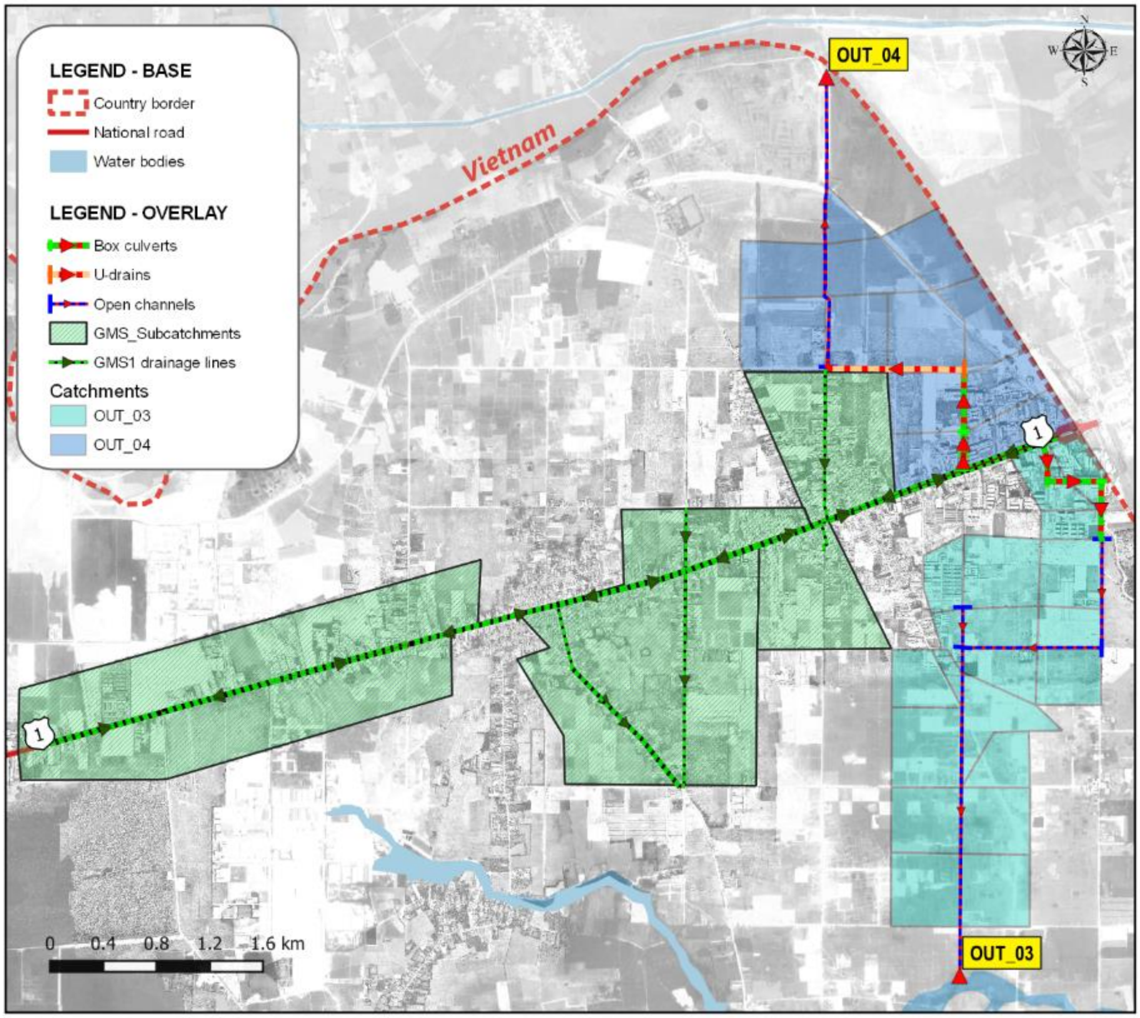
15. Except for the area covered by GMS 1,[4] there is currently no existing overall strategy and roadmap for the sector. The implementation of the new drainage section does not seem to follow an overall strategy but a patching logic following the urban development.

16. Recurrent floods are reported by inhabitants and local authorities. Main stormwater channels are operating properly but the existing urban stormwater infrastructure is not sufficient to ensure proper drainage of the city center.

17. The proposed drainage network shown in Figure 5 follows the natural topography and discharges at low points of the road. As much as possible, the few existing cross-drains will be reused to limit the cost of road cutting and reinstatement.

[4] ADB. Greater Mekong Subregion Southern Economic Corridor Towns Development Project

Figure 5: Proposed Service Areas (stormwater)



Source: Egis, 2021

Table 5: Summary Table of Investment in Bavet (stormwater)

Investment Area	Components
Box culvert	1.9 km
U-drain	1.0 km
Open channel	6.8 km
Outfalls	2

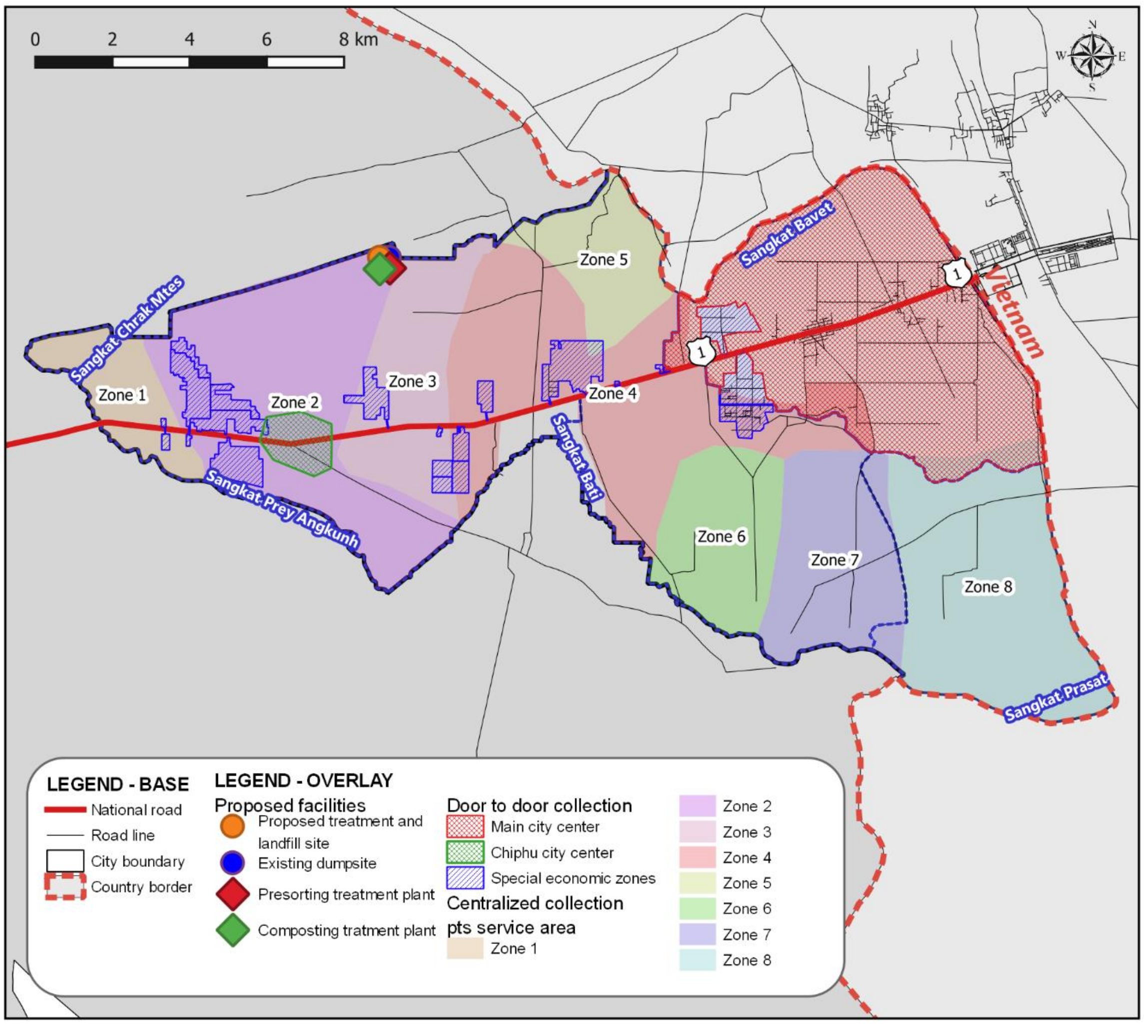
Solid Waste Management

18. It is estimated that 90% of the solid waste generated in Bavet is unsafely managed. The household collection coverage is only approximatively 14%. A large portion of the municipal solid waste (MSW) is also left uncollected and is dumped directly in the nearby natural environment and/or burnt. It is necessary to improve the collection for the whole city.

19. In terms of collection, door to door collection is preferred in the city center while centralized collection is suggested in rural areas until these areas are sufficiently developed to allow for door-to-door collection. Source segregation at markets, with a dedicated centralized collection point, would be an opportunity to increase the sorting of bio-waste and therefore the potential for compost production.

20. In terms of treatment, a sorting plant and a composting plant have been identified as the most appropriate technologies to reduce the amount of waste to be landfilled; to control part of the market for recyclables to increase revenue potential; and to contribute the climate change mitigation. Finally, a controlled landfill is proposed as being the most appropriate disposal system for most small city to avoid the harmful dumping and burning of waste.

Figure 6: Proposed SWM Facilities and Coverage



Source: Egis, 2021

Table 6: Solid Waste Management Sub-Components

Sub-component	Options	Design Capacity
Collection		
Rural area collection	Centralized collection points	
Urban area collection	Door to door collection	
Market biowaste collection	Centralized collection points with segregation at source	
Treatment		
Sorting plant	Sheltered sorting line, managed as an additional flow of the MRF	Designed for 2040
Composting plant	Windrow composting process	Designed for 2040
Landfill	Leachate management: combination of leachate recirculation and off-site treatment at WWTP	Designed for 2030

Table 7: Summary Table of Investment in Bavet (SWM)

Investment Area	Components
Collection	16 compacting trucks
Treatment	1 sorting-plant and 1 composting plant
Disposal	1 controlled landfill

2.2. Medium term (2025-2030)

21. For the medium term it is proposed that master plans are reviewed and updated. It is expected that medium term infrastructure will include:

Wastewater

(i) Staged extension of the network, gravity sewers, pumping stations, and force mains to follow the urban expansion.

(ii) Improvements to the provision of household plumbing and on-site containment and treatment in Rural Areas

Storm Water

(i) Drainage designed and constructed to service continued urban growth and provide drainage to the Chipu area.

Solid Waste Management

(i) Extensions to the landfill and composting sites

2.3. Long term (2030-2040)

22. For the long term it is proposed that master plans are again reviewed and updated to integrate the latest urban settlement and development trends, to respond to any climate trends or new understandings of projected climate changes, and to update safeguard documents. This would also include integration of design and construction across all utilities for water, power, communications and roads.

23. The proposed review will include the success of phase 1 and 2 drainage infrastructure in reducing flooding across the urban center, a review of growth areas for extensions of sewerage and additional pumping stations pipes and house connections, review of the required number of additional collection trucks, cell requirements at the landfill and the operation of the waste sorting and composting sites. The review will inform any required adjustments to the design to respond to changes in areas of enhanced populations growth or to new understandings of projected climate changes based on the most recent climate change science available.

3. Methodology, scope, and limitations

24. Vulnerability per district can be assessed by examining exposure to climate change hazards, sectorial sensitivity and the capacity of the provincial and municipal authorities and the community to adapt to climate change. A staged approach was used to complete this CRAA. Existing information, data on historic climate from previous studies, and GIS analysis were used to assess current exposure to climate change hazards. Then a future-explicit climate change vulnerability assessment was carried out using climate simulation models and GIS models. An assessment of potential risks of climate-sensitive project components to projected climate change and an assessment of climate resilience of the proposed design was followed by identification of possible additional adaptive measures.

25. The project is designed to facilitate long-term sustainable and economic growth in Bavet by developing strategies to improve urban infrastructure. Sector Master Plans identified infrastructure required to meet the future urban needs of Bavet for three planning stages; Short-Term (2020-2025), Medium-Term (2025-2030), and Long-Term (2030-2040) as outlined in section II2 above. However, this report presents an assessment of the infrastructure that is proposed for the short term, i.e. the next 5 years. As the planning has been carried out for the period to 2040, climate change impacts will be assessed based on a design period for project infrastructure to 2040. However, climate projections that are available from previous reports are presented for various time periods. Where possible ancillary information or interpolation was used to determine climate change projections for 2040. However, if there was insufficient information available to make an interpolation, then the projected parameter values for 2050 or 2055 were used to assess vulnerability.

II. POLICY AND INSTITUTIONAL FRAMEWORK

1. Institutional framework

26. Cambodia ratified the UN Framework Convention on Climate Change as a Non-Annex I Party in 1995 and acceded to the Kyoto Protocol in 2002, which entered into force in February 2005.

27. In 2003, the Ministry of Environment (MoE) established the Cambodia Climate Change Office (CCCO), responsible for a wide range of climate change related activities. The status of the CCCO was upgraded from office to department (Department of Climate Change (DCC)) in 2009.

28. In 2015, the Government recognized the importance of environmental protection and climate change in economic development efforts and that many environmental issues are cross-sectoral, requiring effective coordination amongst government agencies, at both national and sub-national levels, and cooperation with all the stakeholders.

29. Therefore, the previous inter-ministerial mechanism for coordination of climate change response, the National Climate Change Committee (NCCC), was replaced with the National Council for Sustainable Development (NCSD). The NCSD comprises high-level representatives (Secretaries and Under-Secretaries of State) of concerned government ministries and agencies, with the Prime Minister as its Honorary Chair and the Minister of Environment as its Chair. Council membership has increased compared to NCCC, covering a greater number of ministries and agencies, and now includes provincial governors.

30. The Department of Climate Change now serves as the Secretariat for the NCSD, acts as the Secretariat of the Cambodian Designated National Authority (DNA) for the Clean Development Mechanism (CDM) and has been actively promoting CDM projects in Cambodia.

31. An important supporter of the disaster management system in Cambodia is the ASEAN Agreement on Disaster Management and Emergency Response (AADMER), a legally-binding regional agreement between the countries in the region. AADMER contains provisions on disaster risk identification, monitoring and early warning, prevention and mitigation, preparedness and response, rehabilitation, technical cooperation and research, mechanisms for coordination, and simplified customs and immigration procedures. AADMER provides support to disaster management in the ASEAN region and assistance in the member countries to enhance the harmonization of regional initiatives.[5] AADMER is also ASEAN's affirmation of its commitment to the Hyogo Framework for Action (HFA).

[5] UNDRR (2019). Disaster Risk Reduction in Cambodia: Status Report 2019. Bangkok, Thailand, United Nations Office for Disaster Risk Reduction (UNDRR), Regional Office for Asia and the Pacific

2. Sector policy

32. The Cambodia Climate Change Strategic Plan for 2014 – 2023 (CCCSP) was developed as the first comprehensive policy document to respond to climate change issues. It aims to advance the development towards a low carbon, resilient, equitable and sustainable society by introducing linkages for supporting a harmonized approach to national development, poverty reduction, and environmental sustainability. The CCCSP outlines strategies to increase the public awareness of climate change, improve the national capacity, enhance community resilience, and reduce national GHG emissions.

33. The Plan sets out eight Strategic Objectives, each with a series of specific strategies that aim to achieve each objective:

(i) Promote climate resilience through improving food, water and energy (FWE) security

(ii) Reduce sectoral, regional, gender vulnerability and health risks to climate change impacts

(iii) Ensure climate resilience of critical ecosystems (Tonle Sap Lake, Mekong River, coastal ecosystems, highlands, etc.), biodiversity, protected areas, and cultural heritage sites

(iv) Promote low-carbon planning and technologies to support sustainable development

(v) Improve capacities, knowledge, and awareness for climate change responses

(vi) Promote adaptive social protection and participatory approaches in reducing loss and damage due to climate change

(vii) Strengthen institutions and coordination frameworks for national climate change responses

(viii) Strengthen collaboration and active participation in regional and global climate change processes

34. The Climate Change Action Plan for 2016-2018 (CCAP) was created to support the implementation of the CCCSP. It identifies seventeen key climate change actions to address the eight strategic objectives presented in the CCCSP. The CCAP presents sectoral Climate Change Action Plans developed by fourteen ministries and government institutions (defining 115 different plans at the sub-national level), aimed towards better adaptation, preparedness and mitigation of climate change impacts.

35. The National Action Plan for Disaster Risk Reduction (NAP-DRR) for 2014-2018, highlights poverty reduction as the primary development priority. NAP-DRR focused on capacity building, mainstreaming DRR, creating synergies between DRR and CCA, increased the pace of institutional reforms and highlighted the role of research and academic institutions in national disaster management (NCDM, 2013).

36. DRR and CR have been mainstreamed into development planning at sub-national levels and are considered as a cross-cutting theme in water resource management, agriculture, and rural development. The National Strategic Plan on Green Growth 2013-2030 focuses on promoting economic development based on green growth principles and environmental sustainability.

37. The government has also incorporated disaster and climate concerns into socio-economic development agendas. The Rectangular Strategy for Growth, Employment, Equity and Efficiency: Building the Foundation Toward Realizing the Cambodia Vision 2050 Phase IV (2018), recognized climate change and disaster risk as development challenges and incorporated adaptation and vulnerability reduction into overarching strategies.

38. Voluntary National Review of SDGs (VNR) report 2019 identifies country needs and priorities aligned to the international SDGs. It highlighted efforts to adapt and deliver the Cambodian SDGs (CSDGs) and their integration within the National Strategic Development Plan (NSDP) 2019-2023, focusing on six prioritized goals: Education, Decent Work and Growth, Reduced Inequalities, Climate Action, Peace and Institutions, and SDG Partnerships.

39. To mainstream the post-2015 development agenda comprehensively across sectors and to guarantee whole-of-government response for disaster risk reduction and climate change adaptation, the Strategic National Action Plan for Disaster Risk Reduction 2019 – 2023 currently being developed is intended to be aligned with the Sendai Framework for Disaster Risk Reduction, the Paris Agreement and the Sustainable Development Goals.

3. Institutional arrangements

40. The Ministry of Environment developed the Climate Change Action Plan 2016-2018, setting guidance for general directorates, departments, and units under its jurisdiction. A Climate Change Technical Working Group (CC-TWG) was officially established by the Minister of Environment and Chair of the National Council for Sustainable Development (NCSD). The CC-TWG brings together all government agencies involved in the climate change response and meets four times per year, including at least two sessions with development partners. It reviews progress in the implementation of Cambodia’s Climate Change Strategic Plan and serves as a forum for coordination and policy dialogue.

41. On December 2, 2019, the National Law Sub-Decree 182 on Functions and Structure of Municipal Administration was adopted and is currently being implemented.[6] The sub-decree defines the functions, structure, roles, and accountabilities of all municipal administrations (MA) in the country. Responsibilities and functions for managing utility services and other activities were transferred to the MA. As a result of these changes, all responsibilities related to wastewater, drainage, and solid waste management are now in the hands of the MA. The Sub-decree creates several offices and units, in particular, a Public Works & Transport, Environmental, Sanitation, and Public Order Office (PWTESPO) in charge of: (i) Urban garbage, and Solid waste management.; (ii) Drainage and wastewater treatment system management. However, due to the recent implementation of the new decree 182, there are currently no dedicated units within the MA for stormwater and wastewater management.

42. MAs are accountable to the Government and the respective line ministries in carrying out their roles. Ministries at the national level are primarily responsible for setting policies, strategic plans, and technical standards to guide the operation of the MAs. Ministries are expected to

[6] Kingdom of Cambodia. 2019. No.182ANK.BK Sub-decree on Functions, and Structure of Municipal Administration. Phnom Penh.

provide technical assistance to MAs. As part of the CCAP process, sectoral Climate Change Action Plans have been developed by ministries and the relevant ministries are responsible for assisting MAs to implement climate change activities.

4. Challenges

43. Some of the key challenges to effective policy implementation are related to the fact that policies are mainly developed by central government agencies and most other actors are insufficiently involved and local communities are effectively excluded. There is also a communication disconnect between national and subnational levels going all the way down to the community level. Coupled with limited technical capacity and finances, political interference, and the absence of functional implementation structures across these levels, effective CCA is limited.

44. The Cambodia Climate Change Strategic Plan 2014 – 2023 acknowledged that limited human and financial resources at the local levels led to a lack of mainstreaming climate change into sub-national development plans. Also, disaster risk management policies and priorities often overlapped with climate policies, and the response capacity could also be improved[7]. A World Bank review in 2017 found that lack capacity, insufficient analytics and the heavy focus on response was still obstructing a systematic approach to disaster management. The report also identified gaps in disaster risk financing and insurance in emergency response, indicating that short-term emergency response costs of flooding exceed the available resources[8].

45. The added responsibility for the MA for the management of public utility services for sanitation, drainage, and solid waste management, as detailed in the new decree 182, has implications for the MA capacity in terms of the additional human resources and capacity development needed to undertake this function. The LCIP feasibility study reports identifies several risks associated with financial sustainability and the ability of the MA to fund the incremental Opex.

46. Specifically, this is related to the ability of Bavet municipality to raise more income through the formulation and agreement of the wastewater and the solid waste tariffs roadmaps and a lack of capacity to carry out regular maintenance and monitoring and inventory.

47. The capacity of the MA is assessed as part of the risk assessment presented in Chapter V.

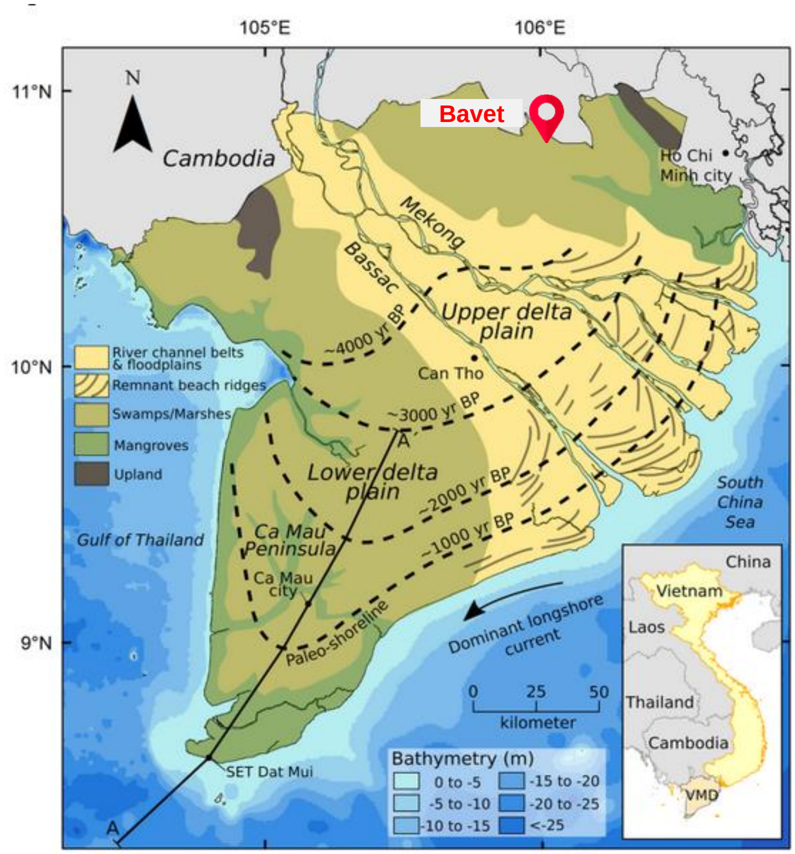
[7] Kingdom of Cambodia. 2013. Cambodia Climate Change Strategic Plan 2014 – 2023. Phnom Penh.
[8] World Bank and GFDRR. 2017. Disaster Risk Finance Country Diagnostic Note: Cambodia. Washington, D.C.

III. RISKS BASED ON CURRENT CLIMATE VARIABILITY

1. Geophysical setting and earthquake/volcano hazards

48. Bavet is located on very flat terrain of the flood plain of the Vàm Cỏ Đông River that flows through Vietnam to the east of Bavet. Elevations are below 20 m above sea level (ASL) and there are wetlands scattered around the city in Svay Rieng and the adjoining parts of Vietnam. As shown in Figure 7, Svay Rieng is technically part of the upper reaches of the Mekong Delta[9] and widespread flooding typical of the Mekong Delta occurs across the Province in the wet season. The area is geologically stable and not considered to be at high risk of earthquakes.

Figure 7: Geomorphology of the Mekong Delta



Source: Zoccarato, C.; Minderhoud, P. & Teatini, P. (2018), 'The role of sedimentation and natural compaction in a prograding delta: insights from the mega Mekong delta, Vietnam', Scientific Reports 8.

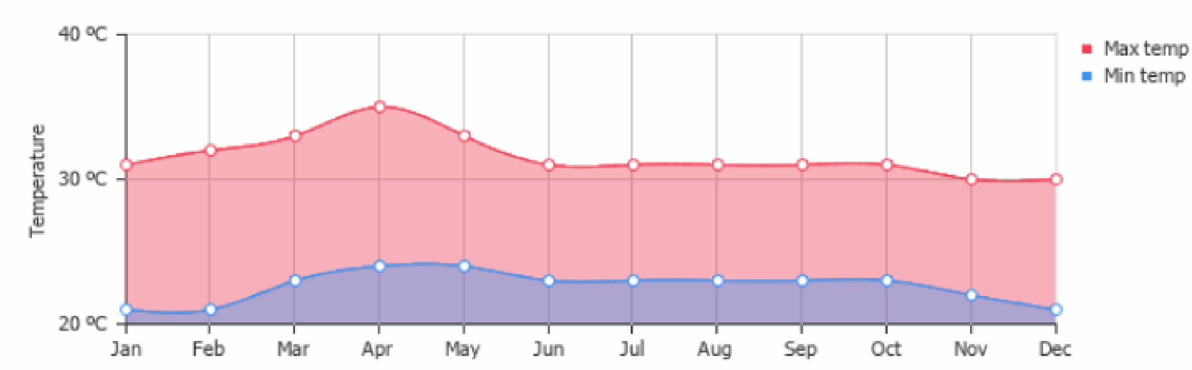
2. Temperature

49. North east winds during the dry season, brings drier and cooler air from November to March, and then south-west monsoon winds bring hotter air in April and early May. The mean maximum temperature is 28°C and the mean minimum temperature is 22°C. Maximum daily

[9] Zoccarato, C.; Minderhoud, P. & Teatini, P. 2018, *'The role of sedimentation and natural compaction in a prograding delta: insights from the mega Mekong delta, Vietnam'*, Scientific Reports 8.

temperatures above 32°C are common before the start of the rainy season and may rise to more than 38°C. Average monthly temperatures for Ho Chi Minh City 63 km to the east of Bavet are shown in Figure 8.

Figure 8: Average temperatures in Bavet (Ho Chi Minh City Station, Vietnam (63km to the East))



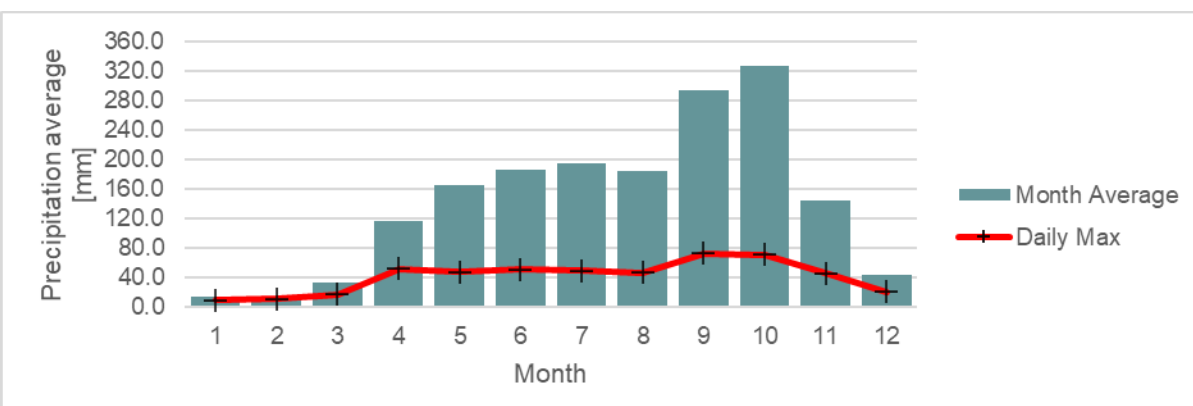
Source: www.weather-and-climate.com, 2019

50. Mean annual temperature across Cambodia has increased at a rate of around 0.18˚C per decade since 1960. The rate of increase is most rapid in the dry season (0.20 - 0.23˚C per decade) and slower in the wet season (0.13 - 0.16˚C per decade).[10]

3. Rainfall

51. Cambodia's climate is tropical monsoon characterized by a rainy season from May to early October which accounts for 90% of annual precipitation and a dry season, from November to April. The average monthly rainfall for Svay Rieng, shown in Figure 9, ranges from 12.4 mm in February to 327 mm in October. Yearly precipitation from 1985 to 2018 is shown in Figure 10. The average annual rainfall during this period varied between 1,300 mm in 2025 and 2,190 mm in 2016. There has been a (not statistically significant) decreasing trend of 22.5 mm per decade.

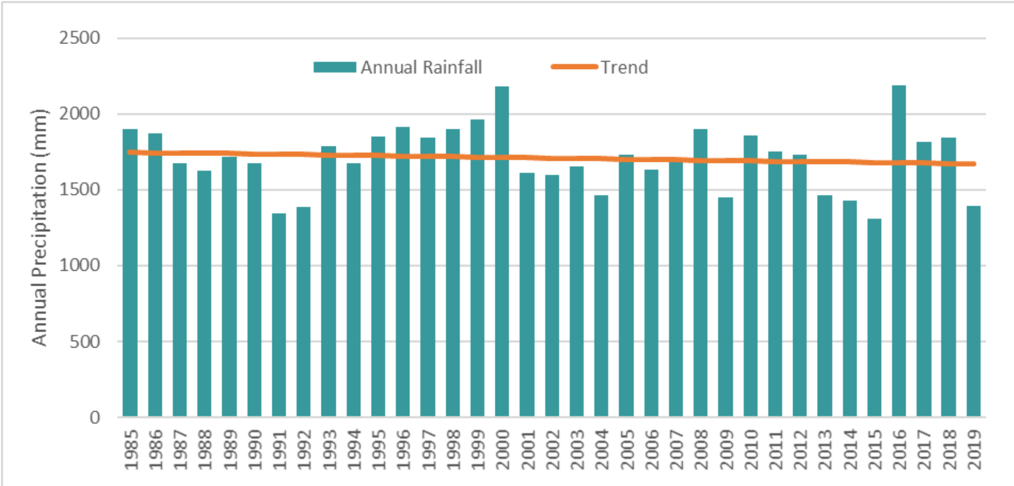
Figure 9: Monthly Average Precipitation in Svay Rieng (1985-2018)



Source: Data from MOWRAM.

[10] GSNCSD/MoE. 2020. Cambodia's Updated Nationally Determined Contribution (NDC). Phnom Penh.

Figure 10: Yearly Precipitation in Svay Rieng (1985-2018)



Source: Data from MOWRAM.

4. Extreme weather events and flooding/storm surge hazards

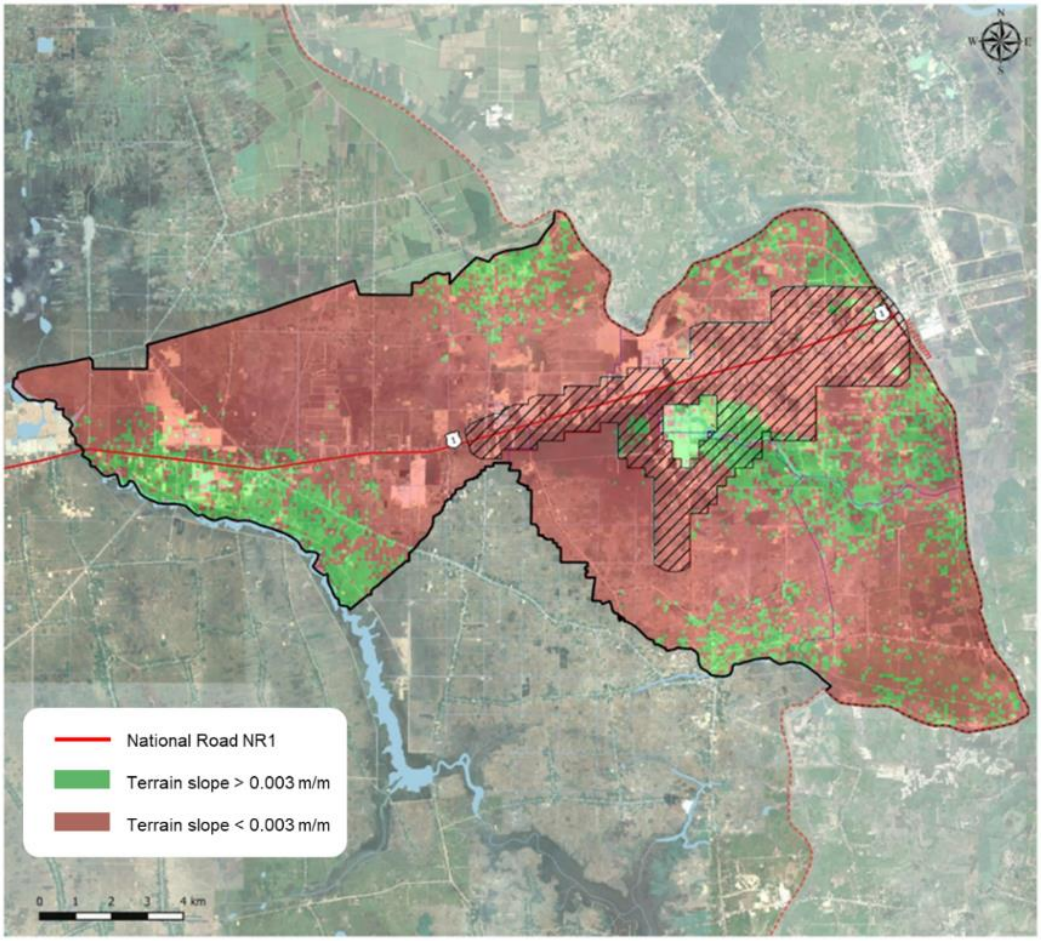
52. The high wet season rainfall means that flooding is common across Cambodia. The remnants of typhoons and other large tropical storm systems produce flooding in the provinces of Battambang, Kampong Chnnang, Kampong Speu, Kampong Thom, Kampot, Kandal, Pursat and Rattanakiri.[11] Flooding in southeastern and central Cambodia occurs between early July and early October due to increased water levels in the Mekong River and Tonle Sap basins (that together cover 80% of the country). Widespread flooding across Cambodia covering many Provinces occurred in 1991, 1996, 2000, 2011 2013 and 2019. At the time, the 2000 floods were considered to be the worst to hit Cambodia in 70 years,[12] until more damaging floods occurred in 2011 and then again in 2013.[13]

[11] GSSD 2015. Cambodia's Second National Communication Under the United Nations Framework Convention on Climate Change. Phnom Penh

[12] NCDM, 2011. Summary Annual Report on Disaster Events in Cambodia from 2000-2010. Phnom Penh.

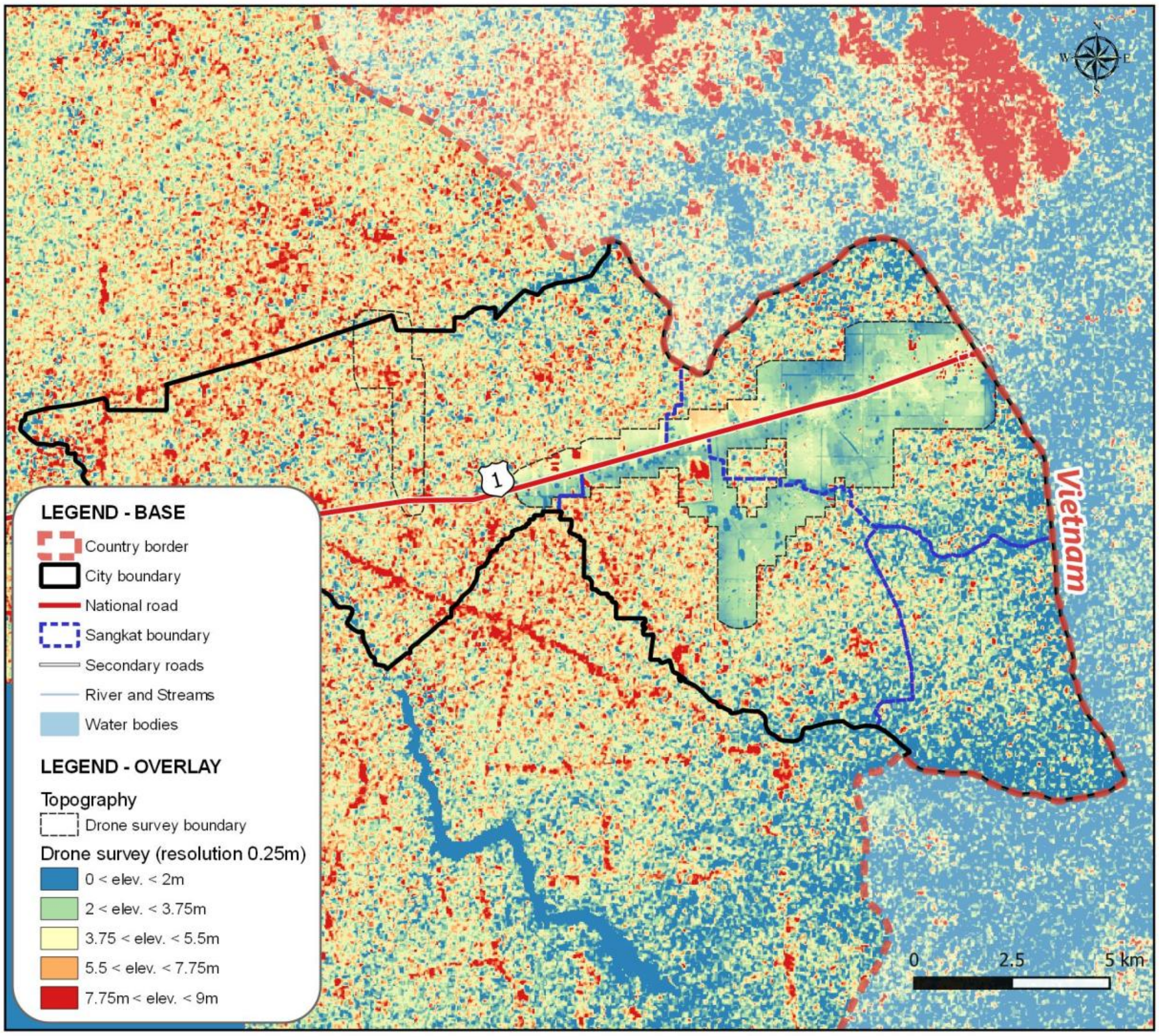
[13] NCDM. 2013. Update on the current flood situation affecting the country, (18 October 2013). Reported in Floodlist; https://floodlist.com/asia/cambodia-floods-recede.

Figure 11: Natural Terrain Slope



Source: Egis, 2021

Figure 12: Raw DTM Elevation Data



Source: Egis, 2021

53. Flooding in Cambodia is often linked to the El Niño-Southern Oscillation (ENSO). La Niña events are often associated with above-normal rainfall over Southeast Asia and sometimes extreme flood events. The recent La Niña event of 2020 saw widespread flooding across Cambodia.

54. Due to the extremely flat terrain (Figure 11), Svay Rieng is downstream of all other weather influences and can flood over very large distances. The province is bisected by NR1 and local rainfall has no natural drainage escape route so areas of free-standing water can form to the north and south of NR1.[14] MPWT's in-house software used for determining the magnitude of flood risk, the Flood Risk Management Interface (FRMI), classifies NR1 as being at low-moderate risk of flooding because of its embankment.

[14] ADB. 2018. Cambodia: Rural Roads Improvement Project III

55. Previous studies into the vulnerability of Svay Rieng Province to flooding have found that the province is vulnerable to flooding. The initial Survey of Rural Cambodian Households carried out as part of the Formulation of the 1st National Adaptation Program of Action to Climate Change (NAPA) found that Svay Rieng was vulnerable to flooding and ranked the province as the 12th highest province out of 21.[15]

56. However, reports of the severity of flooding in the area around Bavet indicate that widespread flooding as a result of the Mekong or other rivers overtopping their banks is not a problem. An assessment of flood vulnerability based on flooding in 2000 carried out in 2003 by the NCDM did not identify extensive flooding and rated the area around Bavet as low priority in terms of flooding[16]. A satellite based assessment of the extent of flooding during the 2012 flood only identified a few small areas of flooding around Bavet.[17]

57. It appears that the major type of flooding in Bavet is localized flooding caused by inadequate drainage being unable to deal with intense rainfall events. A situation that is exacerbated by obstruction of flows due to poor road design (e.g. National Road no. 1) or other anthropogenic activities and interventions such as the purposefully blocking a water drainage system by a Special Economic Zone (SEZ) leaving the surrounding area flooded as reported in the Phnom Penh Post in 2016.[18]

5. Droughts and land degradation/salinity hazard susceptibility

58. Extended periods of drought are now a large concern for human welfare and food security. When coupled with other climatic factors, such as higher temperatures and wind events or unsustainable agricultural and development patterns, droughts can result in land degradation and, if unchecked, in increases in desert land areas or desertification. The heavy reliance of Cambodian farmers on subsistence farming means that delays in the onset of monsoon rainfall have significant negative impacts on rice production. Droughts in Cambodia are caused by failure of the monsoon rains and are often linked to the El Niño-Southern Oscillation (ENSO). El Niño events are often correlated with droughts over Southeast Asia and the opposite phase, a La Niña event, is associated with above-normal rainfall and sometimes extreme flood events.

59. El Niño weather patterns produce a twofold impact; higher-than-average temperatures and reduced monsoon rains that tend to start later in the season. Droughts are common across Cambodia with droughts occurring in various parts of the country in 1995, 1996, 1998 and 2002, 2003, 2004, 2009, 2012, 2015, 2016, and 2019. In 2015/16, Cambodia experienced its worst drought in 50 years with an estimated 2.5 million people affected across 25 provinces.[19]

60. Analysis of the number and frequency of droughts in the region carried out by CSIRO presented maps of drought indicators across the region for the period 1979 - 2007. They found

---

[15] MoE 2005. *Vulnerability and Adaptation to Climate Hazards and to Climate Change: A Survey of Rural Cambodian Households.* Phnom Penh.
[16] National Committee for Disaster Management & United Nations World Food Programme. 2003. *Mapping Vulnerability to Natural Disasters in Cambodia.* Phnom Penh.
[17] Dao, P. & Liou, Y.-A. 2015. *'Object-Based Flood Mapping and Affected Rice Field Estimation with Landsat 8 OLI and MODIS Data',* Remote Sensing 7, 5077--5097.
[18] https://www.phnompenhpost.com/national/svay-rieng-sez-blockage-causing-flooding-pol *Accessed 12/10.2020.*
[19] UNDRR. 2019. *Disaster Risk Reduction in Cambodia: Status Report 2019.* Bangkok.

that the average duration of droughts in Svay Rieng is 13 months and there was up to 7 of these drought events over this period .[20] This represents either an early start to the dry season or a late start to the wet season which has the potential to impact agricultural production. The study found no trend in drought occurrence over this period.

61. Svay Rieng Province is generally presented as being susceptible to drought and is listed as impacted in many of the reported droughts listed above. The initial Survey of Rural Cambodian Households carried out as part of the Formulation of the NAPA found that Svay Rieng was vulnerable to drought and ranked the province as the 8th highest province out of 21.[21] However, an assessment of drought vulnerability within the province carried out in 2003 by the NCDM rated the area immediately around Bavet as a low priority in terms of drought[22] and the Province was not listed as drought effected by the NCDM in the widespread drought of 2015/16.[23]

6. Community perceptions of recent climate change

62. A comprehensive city survey across the Urban Sangkats in Bavet was conducted in December 2019. The subjects surveyed include household (HH) and commercial and institutions (C&I) in the target location. The survey undertaken by the transaction technical assistance facility sought the opinion of specific vulnerable groups such as people with lower incomes (ID-poor), Elders, Female-Headed Households (FHH), and Indigenous people (IP), on key features related to climate change (flooding/ drought/ hot weather) through focus group discussion meetings, shown in Table 8.

6.1. Flooding

63. The FHH and Indigenous groups thought wet season flooding would impact the proposed project components by slowing project implementation. Participants of these two groups had experienced inhouse flooding of more than 20cm that they attributed to not enough drains. They also thought that rainfall had increased in the last 10 years. All groups thought that flooding has gotten worse in the last 10 years. No groups reported damage from flooding.

2 Based on this survey, it has also been estimated that 28% of the population is experiencing flooding in their Phum and 37% in their house at every intense rainfall events. 18% of the population experience average flood depth between 20 and 30 centimeters (cm), and 24% between 30 and 50 cm. For the average flooding event, the Phum is impacted for one day (14%) or more (43%).

64. The survey results backup the assessment of the flood hazard to be related to localized flooding due to poorly performing drainage and as a result project infrastructure will be vulnerable to this type of flooding until the drainage infrastructure has been completed.

---

[20] Katzfey, JJ, McGregor, JL and Suppiah, R. 2014*. High-Resolution Climate Projections for Vietnam: Technical Report.* CSIRO, Australia.

[21] MoE. 2005. *Vulnerability and Adaptation to Climate Hazards and to Climate Change: A Survey of Rural Cambodian Households.* Phnom Penh.

[22] National Committee for Disaster Management & United Nations World Food Programme. 2003*. Mapping Vulnerability to Natural Disasters in Cambodia. National Committee for Disaster Management.* Phnom Penh.

[23] Cambodia Disaster Damage & Loss Information System (CamDi). *http://camdi.ncdm.gov.kh. Accessed 14 April 2021.*

6.2. Drought

65. All groups thought that droughts have become longer in the last 20 years and that their income had been moderately impacted by drought, with reduced income from crops or an agricultural business.

6.3. Hot weather

66. All groups thought that hot weather had worsened health issues for members of their household and thought there are more extremely hot days and more consecutive hot days together compared to 20 years ago.

67. Results of the social survey on opinion of specific vulnerable groups on key features related to climate change (flooding/ drought/ hot weather).

Table 8: Results of social survey on opinion of specific vulnerable groups on key features related to climate change (flooding/ drought/ hot weather).

Group Number participants (total (men/women)	ID-Poor 11(5/6)	Elders 11(5/6)	F HH 9(5/4)	IP 11(5/6)
Flooding				
Do you think flooding in the wet season will impact the proposed project components?	No	No	Yes	Yes
If yes, why?			Slow project implementation	Slow project implementation
Have you experienced flooding in your house?	No	No	Yes	Yes
If yes, what was level of flood water: (a) around the house but not inside, (b) inside the house but not deep, (c) more than 20 cm deep in the house?			(c)	(c)
If yes, what was the cause (a) not enough drains, (b) blocked drains, (c) too much water for the existing drains, (d) sea-level rise, (e) other			(a)	(a)
Have you experienced damage to your house from flooding?	No	No	No	No
Do you think that rainfall has increased in the last 10 years?	No	No	Yes	Yes

Group Number participants (total (men/women)	ID-Poor 11(5/6)	Elders 11(5/6)	F HH 9(5/4)	IP 11(5/6)
Do you think that flooding has gotten worse in the last 10 years?	Yes	Yes	Yes	Yes
Drought				
Has your household income been affected by drought?	Yes	Yes	Yes	Yes
How? (a) Household members with less work, (b) reduced income from crops or an agricultural Business, (c) other	(b)	(b)	(b)	(b)
Did the drought have (a) a large impact, (b) a moderate impact, (c) a small impact?	(b)	(b)	(b)	(b)
Do you think that droughts have become longer in the last 20 years?	Yes	Yes	Yes	Yes
Hot weather				
Have any members of your household had health issues that are made worse by hot weather?	Yes	Yes	Yes	Yes
Do you think that there are more extremely hot days now compared to 20 years ago?	Yes	Yes	Yes	Yes
NOTES: ID-poor = lower incomes, F HH = Female Headed Households, IP = Indigenous people				

Source: Egis, 2021

IV. FUTURE PROJECTIONS

68. There has been very little effort into updating climate change projections for Cambodia in the last 5 years. Generally, climate modeling has been based on older generations of climate models released under CMIP3 and using the IPCC3 Special Report on Emissions Scenarios (SRES) CO_2 scenarios. Climate change modeling reports that present data for Cambodia are summarized in Table 9. The Second National Communication released in 2015, did not provide any recent modeling results and relied on projections from earlier reports. The Climate Futures program of the CSIRO funded by Ausaid used 6 CMIP5 GCM models and Representative Concentration Pathways (RCP) to create climate projections for Cambodia and Vietnam. The study produced downscaled projections from a Regional Climate Model with a resolution of 10 km, with six model runs based on inputs from each of the 6 GCMs. The CSIRO reports present maps of the average value of the projections from the six RCM runs. Because of the higher resolution of the CSIRO RCM, where possible the results of the for RCP8.5 for the 20 year period centered on 2055 are used for projections in this CRVA.

69. To provide more information on the range of individual GCM projections, results from the Royal Netherlands Meteorological Institute (KNMI) Climate Explorer Website are also presented. The Climate Explorer Website supported by the World Meteorological Organization, presents data from the latest CMIP6 models. The data consists of projections from a 13 ensemble of GCMs and is at the resolution of the original models with no downscaling (2.5° x 2.5° grid). Data was downloaded and compared to baseline of 2000 – 2020.

70. A discussion of the selection of projections to use for the design of project infrastructure is presented in section IV. 6 below.

Table 9: Climate Change Modelling Discussed in this Report.

Report	Year Released	Model generation	No. Models	CO_2 future Scenario	Baseline
Second National Communication	2015	CMIP3	2	SRES A2	2002
Climate Futures Program, CSIRO (Ausaid)	2013	CMIP5	6	RPC8.5	1975-2005
KNMI. Climate Explorer (www.climexp.knmi.nl).	2021	CMIP6	13	SSP2 RCP4.5 SSP5 RCP8.5	2000-2020

SRES = CO_2 scenarios developed for the IPCC3 Special Report on Emissions Scenarios
RCP = CO_2 Representative Concentration Pathways developed for IPCC5
SSP = Shared Socioeconomic Pathways
CMIP = Climate Model Intercomparison Project carried out for IPCC3, IPCC5 or IPCC6

Source: Egis, 2021

1. Temperature

71. Climate change models are consistent in projecting an increase in temperature across Cambodia in the future. The projected temperature change for Bavet from CMIP6 GCMs is shown

in Table 10. The table shows the median and range of a 13 ensemble of GCM's projections of mean annual temperature anomalies relative to the mean climate of 2000-2020 under the two scenarios for three 20 year time periods. Average annual temperature for Bavet is projected to increase by 0.5 °C by 2030, by 1.3 °C by 2050 and by 3.1°C by the end of the century under RCP8.5. Projections for 2050 under RCP 4.5 are slightly less out to 2050, but the difference is larger by the end of the century.

Table 10: Range of Projected Mean Annual Temperature Change (°C) for the 2.5° x 2.5° cell containing Bavet Compared to the 2000-2020 model average under the SSP2 RCP4.5 and SSP5 RCP8.5 Scenarios from 13 Model Ensemble.

20 yr period	2030			2050			2090		
Scenario	**Min**	**Av**	**Max**	**Min**	**Av**	**Max**	**Min**	**Av**	**Max**
SSP2 RCP4.5	0.2	0.5	0.8	0.5	1.0	1.5	-0.3	1.6	2.6
SSP5 RCP8.5	-0.7	0.5	0.9	-0.2	1.3	2.2	1.2	3.1	4.5

Source. KNMI. Climate Explorer (www.climexp.knmi.nl).

72. The projected change in seasonal temperature for Bavet from the CSIRO RCM downscaling for the period centered on 2055 compared to the period 1975-2005 under RCP8.5 is shown in Table 11. Temperature changes are projected to be greater at the start of the dry season and least at the later part of the wet season.

Table 11: Projected seasonal temperature change (°C) for Bavet for the period centered on 2055 under RCP 8.5 compared to the period 1975-2005.

Parameter	Value
Mean Annual Temperature (°C)	1.9
April-May Temperature (°C)	1.6
June-September Temperature (°C)	1.8
October-November Temperature (°C)	2
December-March Temperature (°C)	1.8

Source. Katzfey, J., Jiao, X., Suppiah, R., Hoffmann, P., Nguyen, K. C. and Poun, S, Climate change projections for Mondulkiri and Koh Kong Provinces in Cambodia, 2013.

73. **Number of Hot Days.** Modeling carried out by the CSIRO presents projections of the number of days above 35°C which is a measure of potential heat stress conditions. The CSIRO modeling indicates that the number of days above 35°C is projected to change from 0-2 to 7-9.

2. Rainfall

74. The projected change in rainfall from climate models is more variable than it is for temperature. The Second National Communication states that under the A2 scenario, annual rainfall for Cambodia in 2100 would increase between 3% and 35% from current rainfall (2015), depending on location, while under SRES B1 the increase would be smaller. The projected annual

rainfall change for Bavet from an ensemble of 10 CMIP6 GCMs is shown in Table 12. The average projection for annual rainfall from the GCMs used in this study is for little change into the future. With regards to the range of outputs, some models project a decrease, -4% by 2030, -5% for 2050 and -14% for 2090, while others project an increase of up to 14% by the end of the century. The results for RCP4.5 are similar out to 2050, but while the mean projection for the two scenarios is similar, the projections for RCP8.5 show a much wider range.

Table 12: Range of Projected Mean Annual Precipitation Change (%) for the 2.5° x 2.5° cell containing Bavet Compared to the 2000-2020 average under different Scenarios from 10 Model Ensemble.

Year	Scenario	Min	25th	Av	75th	Max
2030	SSP2 RCP4.5	-5	0	3	6	10
	SSP5 RCP8.5	-4	0	3	7	9
2050	SSP2 RCP4.5	-3	-2	1	3	8
	SSP5 RCP8.5	-5	1	3	4	10
2090	SSP2 RCP4.5	-4	-3	1	4	9
	SSP5 RCP8.5	-14	-2	1	5	14

Source. KNMI. Climate Explorer (www.climexp.knmi.nl).

3. Extreme weather events and flooding/storm surge

75. Typhoons making landfall on the coast of Vietnam often impact Cambodia as a tropical depression and can bring widespread heavy rainfall and subsequent flooding. There is a growing level of consistency between global climate models that on a global basis the frequency of tropical cyclones is likely to decrease by the end of the 21st century. A CSIRO report found that the majority of GCMs project that there will be a decrease in tropical cyclone formation off the coast of Vietnam. This is consistent with a previous study by Chand et al 2016 [24]. There is also a general agreement between models that the trade off to the decrease in frequency is an increase in intensity of wind speeds of 1.3 m/s [25], and an increase in rainfall rates of the order of 20% within 100 km of the cyclone center [26]. This indicates that extreme rainfall events that result from tropical depressions crossing Cambodia will decrease in frequency, but each event will bring more rain.

76. Table 13 shows the projected increase in extreme rainfall events from two sources; the KNMI website, and the CSIRO study. Both results are based on outputs from CMIP5 GCM data. The KNMI website presents GCM data in 2.5° x 2.5° pixels. The CSIRO study used CMIP5 models as an input to a 10 km x 10km pixel Regional Climate Model. Both studies found that 1 day extreme events are projected to increase in the future. The KNMI GCM data showed that climate

[24] Chand, S.; Tory, K.; Ye, H. & Walsh, K. 2016., *'Projected increase in El Niño-driven tropical cyclone frequency in the Pacific',* Nature Climate Change 7.
[25] Kang, N.-Y., and J.B. Elsner. 2015. *Trade-off between intensity and frequency of global tropical cyclones.* Nature Climate Change.
[26] Knutson, T.R., McBride, J.L., Chan, J., Emanuel, K., Holland, G., Landsea, C., Held, I., Kossin, J.P., Srivastava, A.K., and Sugi, M., 2010. *Tropical cyclones and climate change.* Nature Geoscience, v. 3, p. 157-163.

models produced a wide range of projected changes. The average of the ensemble used in the CSIRO study is slightly lower than the KNMI data. For the 5 day extreme events, the CSIRO study projected an increase in 5 day events of 17.5mm. These projections are consistent with the projected changes in rainfall that will result from tropical depressions crossing into Cambodia from typhoons landing in Vietnam. Because Bavet is on the border, extreme rainfall would be expected to show the projected increase. The CSIRO study found a 60% agreement in the direction of the change between the models.[27]

Table 13: Projected change in extreme rainfall parameters (mm) for Bavet for the period centered on 2055 compared to the period 1975-2005.

Parameter	Value			
	BL	25th	Av	75th
Maximum 1-day rainfall (mm), KNMI, RCP4.5	140 mm	-56	2 (1.4%)	47
Maximum 1-day rainfall (mm), KNMI, RCP8.5	140 mm	-23	14 (10%)	45
Maximum 1-day rainfall (mm), CSIRO, RCP8.5	160 mm		12.5 (8%)	
Maximum 5-day rainfall (mm), CSIRO, RCP8.5	225 mm		17.5 (8%)	
NOTES: Both are based on CMIP5 models. The KNMI website presents GCM data in 2.5° x 2.5° pixels The CSIRO study used CMIP5 models as an input to a 10 km x 10km pixel Regional Climate Model. BL = Average of the model outputs for the baseline runs (1975-2005).				

Source: KNMI. Climate Explorer (www.climexp.knmi.nl) and Katzfey, J. et al, Climate change projections for Mondulkiri and Koh Kong Provinces in Cambodia, 2013.

77. The MRC State of the Basin Report found no clear trend in the extent of flooding across the Mekong River Basin over the last ten years. However, the economic costs of flooding have shown an increase. The report also found no increasing or decreasing trend in the number of tropical storms over the same period.[28] The MRC basin-wide assessments of climate impact on flood behavior suggests that flooded areas might increase by between 4.6% and 27.3% by 2060 for floods of all return intervals.

4. Droughts and land degradation/salinity hazard susceptibility

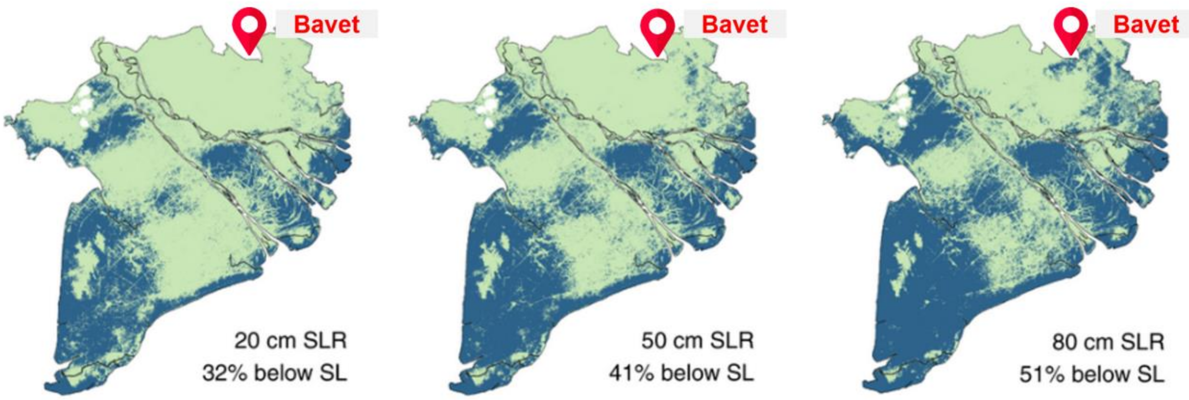
78. The Mekong River Commission state of the Basin Report concluded that a drought could potentially increase across the Basin in the future due to the projected increase in temperatures and changes in rainfall patterns[29]. The CSIRO modelling showed no change in the projected average duration of drought for the 20 year period centered on 2055 under RCP 8.5[30]. Additionally, their modelling projected only a small decrease in the frequency of short 3 month long agricultural droughts which affect rice cultivation in Cambodia.

[27] Katzfey, JJ, McGregor, JL and Suppiah, R. 2014. *High-Resolution Climate Projections for Vietnam: Technical Report.* CSIRO, Australia.
[28] The Mekong River Commission 2019. *State of the Basin Report 2018.* Vientiane Lao PDR.
[29] Refer to footnote 28.
[30] Katzfey, J.; Jiao, X.; Suppiah, R.; Hoffmann, P.; Nguyen, K. C. & Poun, S. 2013. *'Climate change projections for Mondulkiri and Koh Kong Provinces in Cambodia',* CSIRO, Australia.

5. Sea-level change

79. Recent research into the impacts of sea-level rise using updated Digital Elevation Models (DEMs) in the Mekong Delta indicates that the areas of Vietnam that surround Svay Rieng, like much of the rest of the delta, could be exposed to sea level inundation with a rise of 0.8m above current sea level.[31]

Figure 13: Sea level impact in Mekong Delta



Source: Minderhoud, P. S. J.; Coumou, L.; Erkens, G.; Middelkoop, H. & Stouthamer, E. (2019), 'Mekong delta much lower than previously assumed in sea-level rise impact assessments', Nature Communications 10(1), 3847.

80. It is not likely that a sea-level increase of this magnitude will occur during the next 20 years[32]. However, increased sea level downstream could lead to prolonged flooding as drainage will be impeded. It is difficult to make a quantitative assessment of the extent of this impact, so the potential impact of sea-level rise is included in the vulnerability assessment of the impacts of increased flood levels due to larger rainfall events.

6. Selection of Projections of Extreme Rainfall Event Increase for Design of Climate Proof Project Infrastructure

81. In designing drainage for a city that is located on very flat terrain, one difficulty is allowing for enough fall to generate gravity flow and developing adequate drainage cross sectional area to cater to projected water volumes. A number of scenarios that considered the merits of designing the stormwater system for Bavet using a 1 in 2 year return frequency compared to a 1 in 5 year return period was conducted as part of the sector master planning stage.[33] The design storm intensity based on a 1 in 5 year return period is equivalent to a total rainfall of 121mm in one day. The one-day total rainfall for a 1 in 2 year event is 17% lower (101 mm). The comparison found a considerable difference in costs for infrastructure depending on which scenario was used. An

[31] Minderhoud, P. S. J.; Coumou, L.; Erkens, G.; Middelkoop, H. & Stouthamer, E. 2019. *'Mekong delta much lower than previously assumed in sea-level rise impact assessments',* Nature Communications 10(1), 3847.
[32] Katzfey, J.; Jiao, X.; Suppiah, R.; Hoffmann, P.; Nguyen, K. C. & Poun, S..2013. *'Climate change projections for Mondulkiri and Koh Kong Provinces in Cambodia',* Technical report, CSIRO, Australia.
[33] Sector master plan prepared under TA 9554-REG: Southeast Asia Urban Services Facility.

additional impact is that as the size of the cross sectional area increases, the amount of space required for the infrastructure also expands.

82. As there has been no clear trend in the number of storms or the size of extreme rainfall in recent decades across the Mekong River basin, it does not appear to be likely that there will be a large change in extreme event size in the next 10 to 20 years. Analysis of rainfall data from 1985-2019 indicates a (not statistically significant) decreasing trend of 6.3 mm per decade the in maximum yearly rainfall. Projections for increases in typhoon intensity in the future are for an increase of 20% by the end of the century and this indicates that extreme rainfall events will increase in the future. The median projections from the modeling are for an increase of 9% between the baseline (1975 - 2005) and the modeled period (2045 - 2065) under the RCP8.5. Under RCP4.5, the mean model projection is for a small change of less than 2%.

83. To determine a suitable projected increase for the time between the period used to generate the current IDF tables (1985-2018) and the time frame for the revision of the urban infrastructure plan 2030-2040, the average projected extreme event size from the CSIRO modeling was moderated to 5%. It is recommended that each component of rainfall Intensity, Duration and Frequency (IDF) tables can be adjusted by the projected change as a percentage, i.e. 5%. Given the phased nature of the development, which allows for review of drainage performance and additional climate data prior to phases 2 and 3, this is considered suitable for the near-term. The lack of detailed climate change information makes it difficult to provide enough information to devise climate change parameters for different future CO_2 scenarios. The phased nature of the investment means that allowances for extreme rainfall can be reviewed during subsequent phases based on updated climate projections, and the performance of drainage infrastructure from phase 1.

84. Figure 14 shows critical open channel drainage infrastructure in Bavet with the corridor of impact. The available space provided by the road reserve and along the existing canal will be completely taken up by the recommended design (1 in 5 year event size 5% larger due to climate change). The design of the project has been carried out in an effort to reduce the displacement of landowners, under the proposed design, across Bavet there is no need for households to be relocated or have primary structures impacted, but 5 households will lose a proportion of their privately owned residential land.[34] Using the median projected increase due to climate change means that it is still economically feasible to develop a climate change proof design based on a 1 in 5 year event.

[34] Refer to the basic resettlement plan for further details.

Figure 14: Detail of Available Road Reserve for Stormwater Infrastructure in Urban Areas

Source: Egis, 2021

V. ASSESSMENT OF VULNERABILITY TO CLIMATE AND NATURAL HAZARDS

1. Identification of risk hazards

85. The risk of flooding in Cambodia results from two source; flooding due to the annual flooding of the Mekong and other large rivers that drain onto the Mekong Delta, and localized flooding due to heavy rainfall events and poor or obstructed drainage. The hazard assessment indicates that while Bavet is not vulnerable to river flooding, localized flooding is the most important hazard that will impact Bavet by 2040.

86. An assessment of drought vulnerability carried out in 2003 by the NCDM rated the area around Bavet as low priority in terms of drought. And other drought assessments have shown that communes other than Bavet City received the more severe impacts[35]. While drought will continue to impact Bavet into the future, the hazards presented to the proposed infrastructure is minimal.

87. An additional hazard is heat stress due to high air temperatures, particularly if consecutive hot days occur. The number of hot days is projected to increase but will still be less than 10 days in Bavet by 2040[36].

---

[35] International Environment and Disaster Management (IEDM). 2005. *Drought Management Considerations for Climate Change Adaptation: Focus on the Mekong Region.* Oxfam Cambodia. Phnom Penh.

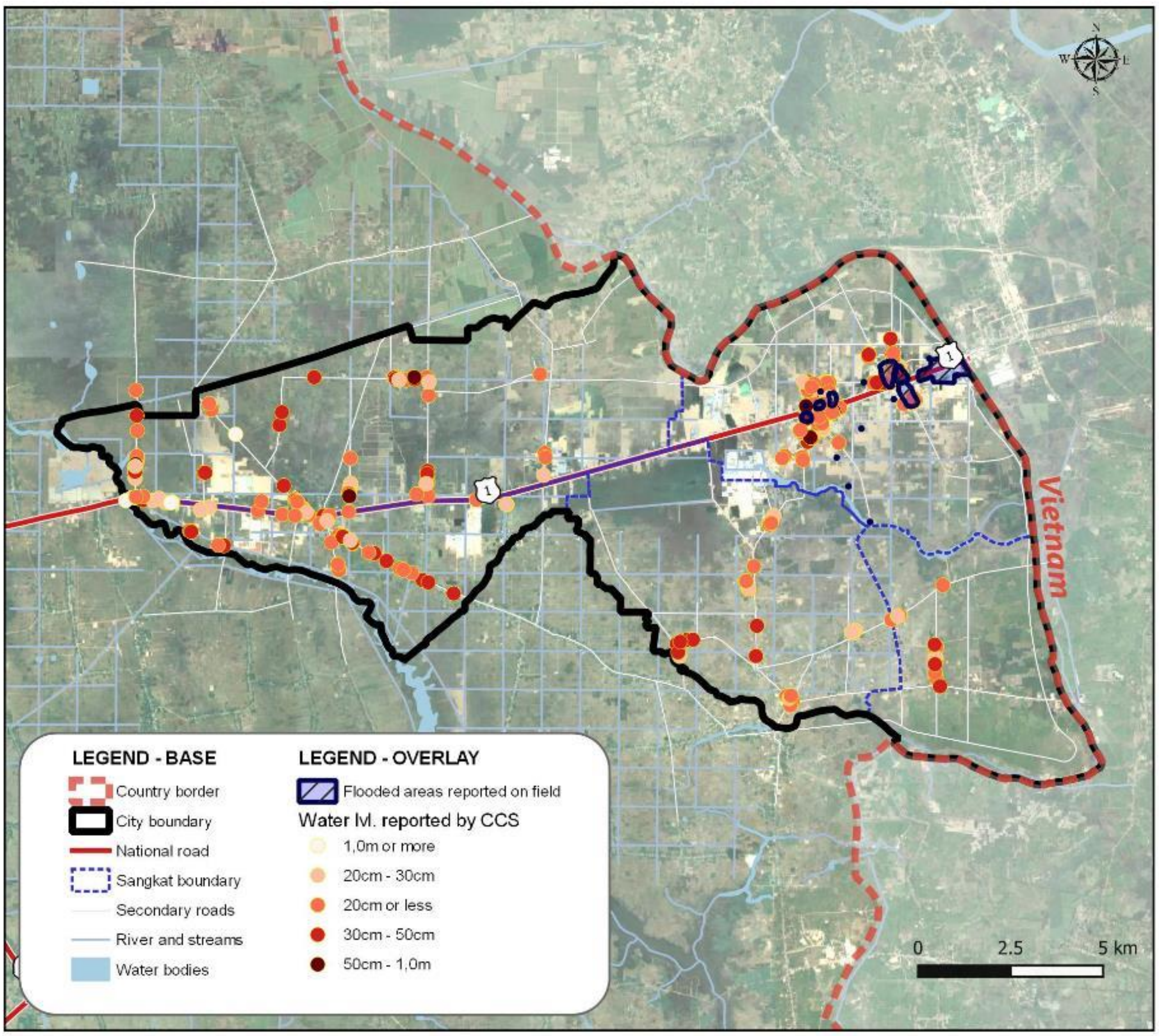
[36] Katzfey, J.; Jiao, X.; Suppiah, R.; Hoffmann, P.; Nguyen, K. C. & Poun, S. 2013., *'Climate change projections for Mondulkiri and Koh Kong Provinces in Cambodia',* Technical report, CSIRO, Australia.

2. Exposure

2.1. Current exposure

88. As part of the survey of specific vulnerable groups undertaken by the transaction technical assistance, participants were asked to identify flood-prone areas in the city. Additionally, any flooding evident during field visits by project staff were also noted. The current extent of the recorded flooding in and around Bavet is shown in Figure 15. The map indicates that flooding is restricted to along roads and in urbanized areas. For Bavet, the area located close to the border has been highlighted as critical.

Figure 15: Flood Prone Areas in Bavet City Identified from CCS Focus Groups and Field Investigations



Source: Egis, 2021

89. Exposure to heat stress is experienced across the city. However, poor households will be more likely to be impacted if they have no access to air-conditioning. The survey of specific

vulnerable groups found that members of all of the groups stated that hot weather had worsened health issues for members of their household.

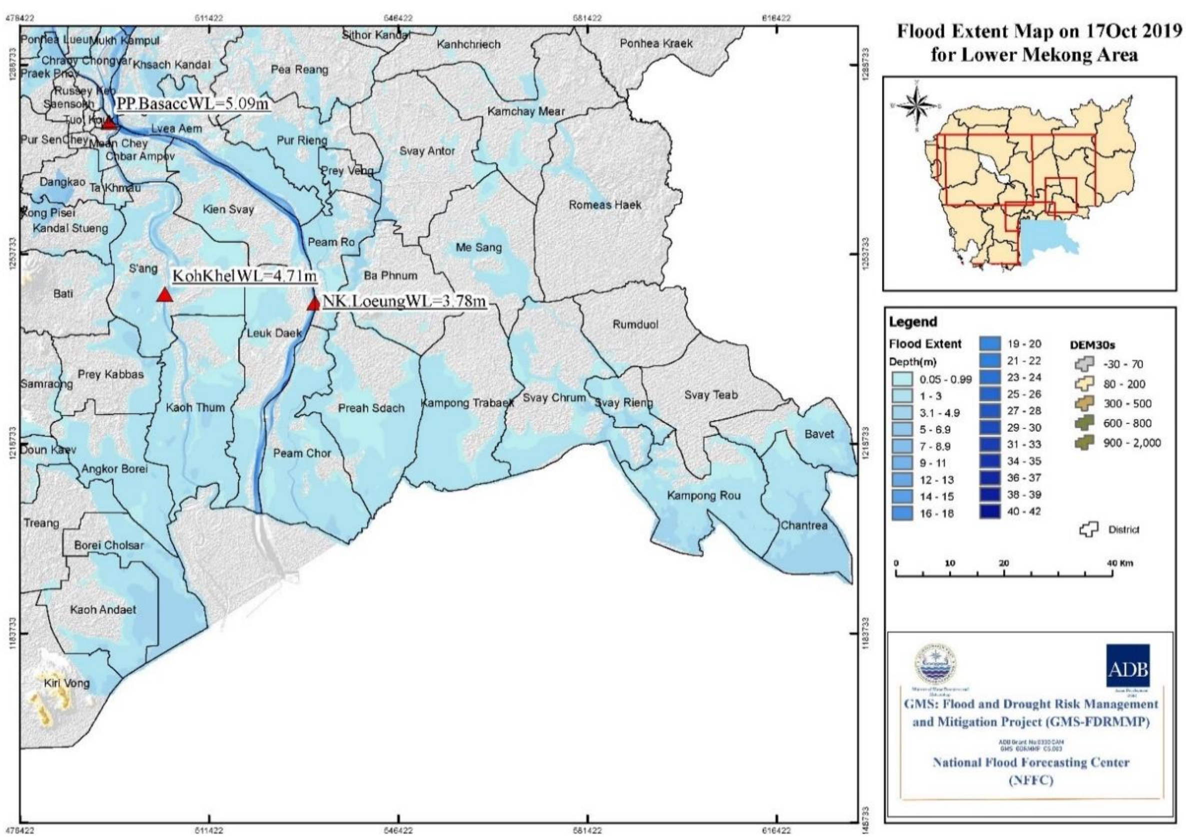
90. Drought is more likely to impact rural areas where reliance on income from agriculture is higher. However, the survey of specific vulnerable groups found that members of all of the groups stated that their income had been moderately impacted by drought. Drought could impact home gardens if there is limited access to water or if the cost of water for use in a garden is prohibitive.

2.2. Future exposure

91. It is difficult to map the extent of future exposure of Bavet city to climate change hazards. Exposure to flooding is from localized flooding due to problems with drainage and the current extent of the problems are not adequately mapped. It is likely that the locations of localized flooding vary as the amount of obstructions in drains also changes. Larger rainfall events may increase the depth and extent of the current problems if business as usual is continued.

92. A recent flood map has been established by the National Flood Forecasting Center (NFFC) within GMS Flood and Drought Risk Management and Mitigation Project for the flooding event that occurred on 17th October 2019. On this day, the cumulated rainfall was 118mm (recorded by Svay Rieng rainfall station), this cumulated is close to 121mm, which is equivalent to a 1 in 5 year return period event (frequency analysis lead by MOWRAM).

Figure 16: Flood Extent Map produced by the National Flood Forecast Center



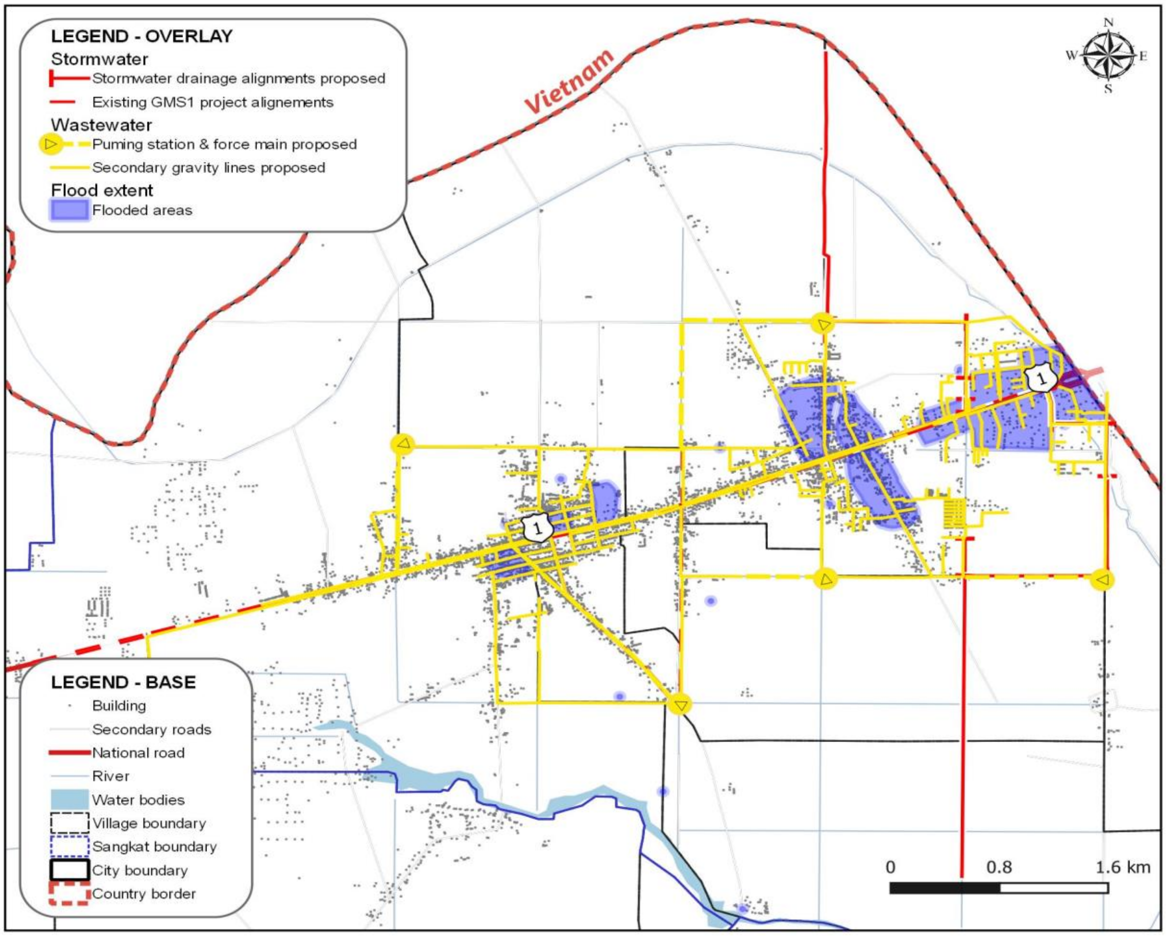
Source: NFCC, 2019

93. There is the potential for drought to increase in frequency or length, though this is not clearly indicated in the climate modeling. Exposure to drought will remain the same as at present. The number of hot days is projected to increase but the exposure will remain the same unless incomes across the city are improved to the extent that air-conditioner ownership increases.

2.3. Identification of exposed project infrastructure

94. Under the climate change scenario extreme rainfall events are projected to be 5% larger. As a result, areas that have been identified as subject to localized flooding will become flooded more often. It is also possible that the areal extent will also increase due to the higher rainfall. However, it is difficult to predict the extent to which localized flooding will increase due to the highly variable nature of local conditions that lead to, or contribute to, any localized event. Additionally, efforts by local residents or the municipality to reduce flooding may be successful but may also merely move the impacts elsewhere. More rainfall also does not necessarily mean greater flood depths as overflows to adjacent drainage catchments could limit absolute flood levels in any one particular location. In order to map the exposure of project infrastructure, all areas in the city where flooding has been identified were mapped. On the basis of the increased rainfall intensity of 5%, it was assumed that the frequency of flooding would increase, and the depth may also increase. Infrastructure planned for these locations was identified as shown in Figure 17 and determined to be exposed to higher impacts due to climate change. All identified infrastructure was classed as highly exposed to flooding regardless of the current depth.

Figure 17: Hazard Exposure Maps Overlaid on Current Infrastructure Network Maps



Source: Egis, 2021

95. The summary presented in Table 14, shows the length of the sections or the number of individual elements of the infrastructure proposed for each component that are exposed to increased impacts due to the projected increase in localized flooding.

Table 14: Exposure of the Project Infrastructure to Flooding

Infrastructure Component	Impacted by flood spots reported from field	% Impacted by flood spots reported from field
Gravity stormwater lines	684 m	7%
Pressure wastewater lines	2977 m	31%
Gravity wastewater lines	8307 m	13%
Pumping station	0	0%
WWTP	Impacted	100%

Infrastructure Component	Impacted by flood spots reported from field	% Impacted by flood spots reported from field
Landfill and adjacent infrastructures	Not impacted	0%

Source: Egis, 2021

3. Sensitivity assessment

96. Sensitivity is the degree to which a system is directly or indirectly affected by a particular climate stimulus such as changes in seasonal temperature or precipitation. An analysis of various sensitivity indicators of the exposed elements will give an indication of the degree of impact (the higher the sensitivity of the system, the higher the expected impacts). In the absence of quantitative information to measure direct or indirect damages, the degree of impact may be assessed qualitatively. This report uses a simple qualitatively assessment of high, moderate or low, based on three components; i) the direct impacts in terms of the number of fatalities, injuries and value of property damage, ii) the length of time that development processes will be impacted into the future, and iii) the costs of recovery.

3.1. Sensitivity to flooding

97. The socio-economic condition of Bavet contributes to the sensitivity of the community to climate change impact. Several anthropogenic activities and interventions have contributed to urban flooding. These are: i) Rapid urbanization linked to economic development contributing to surface impermeability and increased runoff: ii) Rapid development of SEZs with a lack of regulation/enforcement with the same consequences: iii) Limited access to basic services, particularly the current undersized drainage infrastructure and lack of waste management, which has resulted in blocked drainage: and iv) lack of maintenance of drainage lines. As a result, the community of Bavet shows some degree of sensitivity to flooding, but it should be noted that vulnerable groups report little flood damage.

98. The proposed infrastructure such as pipes and pumping stations will be sensitive to inundation and damage due to moving floodwater. Additionally, any embankments will be subject to erosion during heavy rainfall events and possible undercutting from fast flowing floodwaters.

Figure 18: Ta Pov River – Solid Waste blockage

Source: Egis, 2021

3.2. Sensitivity to drought *(land degradation/soil erosion)*

99. Risks and uncertainties that are often associated with the pronounced contrast between the wet and dry season are embedded in the practice of agriculture, and there is considerable experience of coping and risk management strategies among Cambodian people working in this sector. However, in the face of climate change, the magnitude and frequency of stresses and shocks is changing and, therefore, the sensitivity of farmers to drought is increasing[37]. The perception in the community is that droughts do have an impact through reduced income from crops or agricultural businesses.

100. Extended droughts have the potential to require water restrictions in the City reducing influent volumes into the WWTP. This can have effects on wastewater treatment processes efficiency and associated operational costs. As influent flows decrease, there is less water to dilute contaminants potentially increasing pollution concentrations in downstream effluent.

101. The volume of inputs into the WWTP in the future will be influenced by a range of factors as the system is developed over the short and medium terms. The review proposed for the long term will need to consider the future requirements of wastewater treatment for Bavet City and this review will need to include a review of measured and projected changes in the frequency and intensity of droughts.

[37] Phaloeun, C., Kimngoy, C. and Bopreang, K. 2015. *Drought Conditions and Management Strategies in Cambodia. Chapter 4 National Reports; Cambodia. In Tsegai, D. and Ardakanian, R. (Eds). 2015. Proceedings of the Regional Workshop on Capacity Development to Support National Drought Management Policies for Asia-Pacific Countries, 6-9 May 2014, Hanoi, VietNam.* UN-Water Decade Programme on Capacity Development (UNW-DPC). Geneva, Switzerland.

102. Drought will continue to impact the community of Bavet into the future but the sensitivity of the proposed infrastructure to drought in the short and medium term is classified as low.

3.3. Sensitivity to extreme heat events

103. Extreme heat events will have increasing impacts on the community of Bavet into the future. There is the potential for increased temperature to have impacts on the WWTP and the solid waste management components. Warmer temperatures can increase the bacterial reaction rate which reduces the density of settled sludge. Higher temperatures can also increase the formation of N_2O during the denitrification processes. The preference for the lower technology Waste Stabilization Ponds system reduces these impacts.

104. The sensitivity of the proposed infrastructure to 10 extra hot days per year is classed as low.

4. Adaptive capacity assessment

105. Current vulnerability is a result of past adaptation to climatic variability; thus, potential vulnerability is a function of current vulnerability and current adaptive capacity. The challenges in operationalizing the country's policy and strategic directions (outlined in Section III.2), into tangible outcomes at the municipal and commune level means that at the local level, adaptive capacity is often limited.

106. A UNDRR report in 2019 found that while the country's policy and strategic directions lay a solid framework for coherence, efforts to operationalize these plans for tangible outcomes at the local government levels remains to be achieved[38].

107. Reviews and lessons learned of other infrastructure development projects, such as GMS1[39], GMS2[40], and similar projects in Cambodia found that most of the MA employees lack skills in engineering design, asset management, financial systems, and the operation and maintenance of public services infrastructure (drainage, sewerage, and solid waste management). This lack of capacity highlights the need for capacity building related to the operation of project infrastructure as well as the capacity for planning sustainable and climate change resilient expansion of the services.

108. The capacity of the Bavet municipality to deal with the impacts of floods and droughts was assessed. Six (6) factors were used to assess the capacity of the Bavet Municipal officials to efficiently reduce some of the impacts of climate change. These are: 1.) economic wealth; 2.) technology; 3.) Institutional; 4.) Infrastructure; 5.) information; and 6.) social capital. For each of the six factors, the capacity of the Bavet municipal officials was assessed against the criteria presented in an "Ability of The Local Government Official to Deal with The Impact of Hazards" table (see appendix 2). The results of the assessment presented in Table 15 indicate that Bavet Municipality has only a medium-low to medium capacity to respond to extreme events. As a result,

---

[38] UNDRR. 2019*. Disaster Risk Reduction in Cambodia: Status Report 2019.* Bangkok, Thailand
[39] ADB. Greater Mekong Subregion Southern Economic Corridor Towns Development Project
[40] ADB. Second Greater Mekong Subregion Corridor Towns Development Project

any impacts to infrastructure that result from flood events will be exacerbated by a limited capacity to respond to the impacts. The full description of the adaptative capacity factors is presented in Appendix 1.

Table 15: Assessment of Adaptive Capacity of Bavet Municipal Officials.

Adaptive Capacity Factor	Capacity Assessment	Description
Economic Wealth	Medium (3)	Resources limited to assistance for priority areas only Most people in the area have limited access to resources Reliant on international aid for flood recovery The Municipality has limited experience in devising and collecting tariffs
Technology	Medium-Low (2)	Limited equipment and facilities for assistance and limited communication Not adequate for extreme events Some limitations due to technical capacity
Institutional	Medium (3)	Officials and community leaders are aware but management set-up to respond to a hazard is non-existent. Relevant processes, procedures and legislations are passed at the National level but implementing guidelines still have to be formulated The relevant Ministries are tasked with providing assistance and capacity building
Infrastructure	Medium-Low (2)	Infrastructures are available but there are no facilities that can be used to respond to a hazard Transport services in some possibly affected areas are not available No central disaster management center in the Municipality
Information	Medium-Low (2)	Some degree of awareness of Municipal Officials and stakeholders Communication strategies are in place, but procedures are not yet in place
Social Capital	Medium-Low (2)	There is some degree of willingness of the leaders to allocate funds to build adaptive capacity of the Municipality Staff have been transferred from relevant ministries so should have some skills Some agencies and NGOs are available and have skills to assist specific sectors during occurrence of hazard There is a team with basic skills for emergency response

5. Risk assessment

109. The purpose of risk assessment, in the context of climate change, is to identify risks that may be induced or exacerbated by climate change and to evaluate their effects and likelihood (see Appendix 2). This procedure also allows the climate change risks and subsequent adaptive responses to be prioritized with confidence and compared equitably with other risks, resource

availability and cost issues (including works) that the local authority faces. The assessment of risk is carried out in a three-step process:

Step 1: Assess likelihood of hazard scenario

Step 2: Assess consequence of hazard occurring

Step 3: Evaluate the risk

5.1. Likelihood of hazard scenario

110. For each time step in the planning horizon, the likelihood (or probability) of flooding impacting project infrastructure is assessed. Assessment is based on the current likelihood and the projected climate change. A scale of 1-6 was used, with L1 = Rare and L6 = Certain, based on the Table of Descriptors presented in Appendix 3. The calculated likelihood of impacts from flooding hazard for each element of infrastructure for each component is presented in Table 16 to Table 18.

5.1. Consequences of hazard occurring

111. In this step the level of the impact (consequence) of the flooding hazard on the project infrastructure is assessed. The assessment is formed from a combination of inputs; the adaptive capacity assessment, the GIS analysis showing the number of km or the number of components that are exposed, and the estimate of the degree of impact based on the sensitivity analysis. The consequences are categorized using the Descriptors of Consequence Table presented in Appendix 1, with C1 = Negligible and C6 = Extreme. The calculated Consequences of impacts from flooding hazard for each element of infrastructure for each component is presented in Table 16 to Table 18. The details of the specific protection features mentioned in the Comments column are discussed in Chapter VI.

Table 16: Calculated Likelihood and Consequence of Impact from Flooding Hazard for the Infrastructure Element of the Wastewater Component.

Infrastructure Elements	Impacts	Likelihood	Consequence	Comments
Gravity lines (66km)	8,307 m or 13% exposed Erosion by moving floodwaters Undercutting or damage of bridge crossings	3 Possible	2 Minor	Consequence is reduced as protection included in drainage rehabilitation (see discussion below) No significant environmental impacts identified aside from localized disturbance
Pumping Stations 6	Some may be exposed to minor drain flooding	3 Possible	3 Moderate	Enclosure design should include management of flooding

Infrastructure Elements	Impacts	Likelihood	Consequence	Comments
Pumping Mains (9.5 km)	2,977 m or 31% exposed Erosion by moving floodwaters Undercutting or damage of bridge crossings	3 Possible	2 Minor	Consequence is reduced as protection included in drainage and road bridge rehabilitation
WWTP	Increased localized flooding	4 Likely	2 Minor	Design should include management of localized rainfall at projected higher event size

Table 17: Calculated Likelihood and Consequence of Impact from Flooding Hazard for the Infrastructure Element of the Stormwater Component.

Infrastructure Elements	Impacts	Likelihood	Consequence	Comments
Box culverts (6.6 km)	City wide increase in the size of extreme events leading to increased amount of water required to be removed 684 m or 7% exposed	4 Likely	2 Minor	Higher event size is incorporated in design
Open channel (1.9 km)		4 Likely	2 Minor	
Outfalls 4		4 Likely	3 Moderate	Reduced flow due to higher water levels in outlet canals leading to flooding
U-drain (1 km)		4 Likely	2 Minor	Incorporated in design

Table 18: Calculated Likelihood and Consequence of Impact from Flooding Hazard for the Infrastructure Element of the Solid Waste Management Component.

Infrastructure Elements	Impacts	Likelihood	Consequence	Comments
Landfill	Stormwater system could be overwhelmed Leachate could be released	2 Unlikely	4 Severe	Design will incorporate future event size
Sorting Plant	Damage to building due to stronger wind events	1 rare	2 Minor	Built to national standards
Composting Plant	Localized flooding Leachate could be released	2 Unlikely	2 Minor	Design will incorporate future event size
Collection infrastructure	Localized flooding at collection site	2 Unlikely	2 Minor	Drainage improvements will minimize localized flooding

5.2. Evaluation of risk

112. The results from the analysis of the likelihood and consequence are used to calculate the risk of each hazard scenario. Risk (R) is calculated as a function of the likelihood of a hazard impacting an infrastructure element, a community, or an ecosystem (L) and the consequences of that impact, (C).

$$R = L * C$$

113. Verbal descriptors can be applied to the calculated risk of each hazard scenario using Table 19. This makes it easier to quickly compare the impacts of climate change on each project component. For example, an activity that is likely to occur (4) but only has moderate (3) consequence has a risk of Moderate. It should be included in planning but given lower priority.

Table 19: Verbal Descriptors of Calculated Climate Change Risks.

Likelihood	Consequence						
		C1	C2	C3	C4	C5	C6
	L1	Low	Low	Low	Low	Low	Low
	L2	Low	Low	Low	Moderate	Moderate	Moderate
	L3	Low	Low	Moderate	Moderate	Moderate	High
	L4	Low	Moderate	Moderate	High	High	High
	L5	Low	Moderate	Moderate	High	High	Extreme
	L6	Low	Moderate	High	High	Extreme	Extreme

114. The assessed likelihood and consequences of impacts of increased flooding due to the projected climate change for each of the elements of the project components presented above are used to calculate the risks shown in Table 20.

Table 20: Calculated Risk from Flooding Hazard for the Infrastructure Element of The Project Components.

Infrastructure Component	Infrastructure Elements	Risk Calculation		
		Likelihood	Consequence	Risk
1. Wastewater	Gravity lines (66km)	3 Possible	2 Minor	6 Low
	Pumping Stations 6	3 Possible	3 Moderate	9 Moderate
	Pumping Mains (9.5 km)	3 Possible	2 Minor	6 Low
	WWTP	4 Likely	2 Minor	8 Moderate
2. Stormwater	Box culverts (6.6 km)	4 Likely	2 Minor	8 Moderate
	Open channel (1.9 km)	4 Likely	2 Minor	8 Moderate

Infrastructure Component	Infrastructure Elements	Risk Calculation		
		Likelihood	Consequence	Risk
	Outfalls 4	4 Likely	3 Moderate	12 Moderate
	U-drain (1 km)	4 Likely	2 Minor	8 Moderate
3. Solid Waste	Landfill	2 Unlikely	4 Severe	8 Moderate
	Sorting Plant	1 rare	2 Minor	2 Low
	Composting Plant	2 Unlikely	2 Minor	4 Low
	Collection infrastructure	2 Unlikely	2 Minor	4 Low

115. The calculated risk for project components ranges from low to moderate. The highest calculated risk (12 Moderate) is that the outfalls will not function due to flooding in the canals that they are proposed to empty into, leading to the drains backing up and contributing to localized flooding. All components of the drainage system are at moderate risk from increased flooding. The potential for localized flooding impacting pumping stations, the WWTP, and the landfill site leads to a moderate risk for these components. The vulnerability of specific infrastructure elements of each component is discussed below.

6. Vulnerability of infrastructure

116. The projected increase in temperature and the number of hot days will potentially put added stress on project components. The smart city asset management system and improved institutional capacity will assist in managing these changes into the future.

6.1. Wastewater

117. The projected higher extreme event size of 5% means that higher localized flooding could impact infrastructure particularly pumping stations and higher flows in canals could expose pipes where they have to cross drainage canals. The design of bridge crossings and pump housing will reduce this risk.

118. The site for the proposed WWTP is currently subject to flooding of up to 0.5 m. The improved urban stormwater drainage that is proposed for the city as part of the project will reduce the impacts of flooding in urban streets. And as drainage canals around the area of the WWTP site are rehabilitated, localized flooding will be reduced. Lager extreme rainfall events means that onsite localized flooding at the proposed WWTP site will become deeper and drainage designed as part of the treatment plant will need to cater to larger event size.

6.2. Stormwater drainage

119. The projected increase in rainfall will result in an increase in the amount of water that will need to be moved via the proposed drainage improvements which leads to the moderate risk

assessment. The use of a designed rainfall event that takes the projected increase in extreme event size of 5% into account will reduce the risk. The current flooding that occurs in Bavet is related to poorly designed/maintained drains not to river flooding. Therefore, the proposed component including improvements to the overall connectivity and maintenance of the drainage system will improve the overall flow within the system and will minimize risks. Any flooding that occurs around water bodies will continue and may increase in area slightly, although this will be offset by increased evaporation due to the projected higher temperatures.

6.3. Solid waste management

120. Both the existing landfill site and the identified alternative location have been assessed as not subject to flooding. While this is not likely to change given the projected rainfall increase of 5%, there is a moderate risk of impact due to localized flooding overwhelming the stormwater management facilities leading to leachate leaving the site. The design of the new landfill will require a water management plan that will handle extreme events of the projected larger size.

6.4. Other infrastructure

121. Other infrastructure such as access roads and waste collection stations are also at risk from localized flooding. The proposed improvements to drainage will minimize this risk and the proposed reassessment of the master plan before commencement of later stages should identify any new impacts. Drainage for access roads incorporates increased extreme event size of 5%.

VI. ADAPTATION

1. Contribution of project components to adaptation

122. By assisting the Bavet municipality to develop climate change sensitive planning, the project has been designed to decrease the vulnerability of Bavet to the impacts of Climate Change, to improve the resilience of the community, and to improve the adaptive capacity of the Municipal Officials and the community. Each component contributes to improving the capacity of Bavet to adapt to climate change in a number of ways as outlined in below.

1.1. Stormwater drainage

123. The current drainage system operates in effect as a combined drainage and sewage system and is poorly maintained and unconnected. The rehabilitation and expansion of the drainage system will improve connectivity and increase the efficiency of the system. This will decrease the exposure of the city to flood hazards by reducing blockages that increase the extent and length of flood events. It will also decrease the vulnerability of Bavet to the impacts of climate change by minimizing flood damage through efficient and quick removal of floodwaters. Improvements to the system and the construction of well-designed outlets will also decrease the sensitivity of the community by reducing negative health impacts from wastewater contamination. Provision of green spaces around the existing water bodies offers a soft solution for adaptation and will contribute to mitigation.

1.2. Wastewater

124. The provision of properly treated wastewater will decrease the vulnerability of the city by decreasing the number of households exposed to wastewater during localized flooding events. It will also increase the resilience of the population by improving the ability of households to recover from floods by reducing the impact of diseases from floodwaters on the community and the health system. Additionally, proper treatment of wastewater onsite where sewage treatment is not available will increase the resilience of the population by minimizing health risks during localized flooding events.

1.3. Solid waste management

125. Proper management and disposal of solid waste will increase the resilience of the population by improving the health and wellbeing by reducing exposure to unhealthy waste and minimize health risks during both flood events and drought. Ecological solid waste management will contribute to improved air quality and decrease the exposure of the community by removing waste blocking the drainage system that increase the extent and length of flood events.

1.4. Contribution to international/national climate change commitments

126. The project also contributes to Cambodia's international commitments as outlined in. Cambodia is a signatory to the Paris Agreement and the project contributes to climate change

commitments by supporting Priority Outcomes of the Cambodia Climate Change Strategic Plan 2014 – 2023. Project components also contribute to international Sendai Framework Disaster Risk Reduction commitments by supporting Priority Area Objectives of the National Disaster Risk Reduction and Management Plan 2011-2028. Additionally, the project contributes to Cambodia's international commitments to achieving the United Nations Sustainable Development Goals by supporting Strategic Goals of Cambodia's Rectangular Strategy for Growth, Employment, Equity and Efficiency: Building the Foundation Toward Realizing the Cambodia Vision 2050 phase IV.

Table 21: Contribution of Project Components to International Commitments

Infrastructure Component	Cambodia Climate Change Strategic Plan 2014 – 2023 Priority Outcomes/Outputs	Strategic National Action Plan for Disaster Risk Reduction 2008 ~ 2013 Priority Area Objectives	Rectangular Strategy - Phase 4 Strategic Goals
Master Plans	• Urban transport infrastructure planning and development climate proofed.	• Hazard risk information used in land-use planning and zoning programs to prioritize adaptation measures. • Hazard risk information used in building design.	• Climate resilient infrastructure master plan for urban areas supports clean water network master plan. • Climate resilient technologies Incorporated into ecosystem management and socio-economic development.
Wastewater	• Wastewater management climate-proofed through integrated measures. • Climate resilience promoted	• Hazard information used in the installation and access of sanitation facilities.	• Climate resilient infrastructure master plan for clean water network developed and implemented. • Wastewater management strengthened using climate-friendly technologies.
Stormwater	• Water infrastructures developed and rehabilitated and climate proofed through introduction of new technologies.	• Hazard information used in the development, rehabilitation, and access of water infrastructures.	• Climate resilient integrated water infrastructure management plan developed and implemented.
Solid Waste	• Solid waste management climate-proofed through integrated measures.	• Hazard information used in the installation and access of sanitation facilities.	• Climate resilient integrated water infrastructure management plan developed and implemented. • Solid waste management plans strengthened using climate-friendly technologies.

2. Proposed adaptation measures to cope with climate change impacts

127. The largest risks identified in the risk assessment are related to the potential for increased localized flooding due to the projected increase in extreme rainfall events of 5%. Therefore, adaptation measures are related to strategies to decrease these impacts. The major adaptation is a reappraisal of the projected extreme rainfall size used in the design of the drainage infrastructure. Sensitivity assessment carried out during the design phase indicated that an increase in extreme event size will lead to an increase in stormwater flows requiring drainage infrastructure to be 20% larger. Additionally, the improvements in the connectivity of the system and construction of outfalls to rivers will increase efficiency and will minimize the extent and duration of localized flooding. The net result will be a reduction in the impacts of localized flooding across the serviced areas despite the increased size of rainfall events.

128. The larger extreme event size means that localized flooding will increase in extent in areas not adequately serviced by drainage lines. Therefore the WWTP will need to be isolated from the surrounding area that is currently flood prone and will require higher embankments to ensure protection from external flood waters and internal water management designed to manage rainfall events 5% higher than at present.

129. Similarly, the landfill site will also require flood water management designed to manage rainfall events 5% higher than at present. The adaptation options for specific infrastructure components are developed below.

130. As part of the feasibility study, the transaction technical assistance also developed an institutional strengthening plan, which outlines capacity-building tasks for each sector, covering the following areas 1) Improvement of the Regulatory Framework, 2) Improvement of the Institutional Arrangements, 3) Provision of managerial and technical programs, 4) increasing global knowledge of the communities.

2.1. Stormwater drainage

131. The improvements to the drainage are in themselves a climate change adaptation. By improving and rehabilitating drains, the ability of Bavet city to recover from high rainfall events will be improved. The master plan sensitivity analysis allowed for the design to maximize the utilization of road and canal reserves while minimizing the need for land acquisition and relocation. The sensitivity analysis determined that to allow for an increase in extreme rainfall events of 5%, the average pipe/channel section would need to be increased by 20%. The sensitivity analysis also showed a considerable difference in costs for infrastructure depending on which return period was used. By allowing for a projection of climate change for the short term, with review before the implementation of the long term, the proposed infrastructure was able to be designed for a 1 in 5 year event. The implications for the potential for maladaptation due to different climate change projections are discussed below in section VI.4.

2.2. Wastewater

132. Pipes will be laid along road corridors and protection from localized flooding will be provided by a road easement design that includes the installation of appropriate drains designed to cater to the projected larger extreme event size. The proposed pumping stations are not located in areas identified as being currently exposed to localized flooding and the design of the housing that already incorporates protection from inundation will be sufficient.

133. Where pipelines cross streams or drainage canals, they will require protection from floods when drains are overtopped during rare extreme flood events greater than the designed 1 in 5 year events. The protection of pipelines from higher flood levels will be carried out as part of the design of bridge crossings that should already provide protection from flooding.

134. An education campaign backed up by legislation will be used to improve onsite management of existing septic tanks and improve the protection of tanks from localized flooding during higher rainfall events.

135. To minimize impacts, the wastewater treatment plant will be built with flood protection measures incorporated. The WWTP is designed with the stabilization ponds volumetry developed by means of dykes with a 1m height security implemented over the effective capacity of the ponds. Additionally, road structures are scheduled to be developed on dykes for maintenance needs. Additional tree planting could be considered after site development to reduce the rainfall-runoff.

2.3. Solid waste

136. The solid waste facilities are not exposed to climate change impacts. However, the stormwater management system design for the landfill will be designed using the current extreme rainfall event size +5%, adding an extra 11% to the costs. The majority of the leachate will be recirculated back into the landfill mass, with the excess being sent off-site for treatment at the WWTP. The projected increase in extreme event rainfall of 5% is not expected to have a large impact on this process as the extra leachate produced will be within the designed capacity redundancy and excess leachate can be pumped back into the landfill.

3. Prioritization of measures

137. The present socio-economic condition of the city increases the communities' sensitivity to hazards (rapid development of SEZs and correlated urbanization leading to solid impermeabilization, and limited access to basic services). And while the National Government has made steps to developed policies and infrastructure to manage climate change hazards and disaster risks (section III.2), there are still issues with implementation and technical capacity at the subnational level. However, based on the risk assessment (section VI.5), climate-induced hazards are expected to have low to moderate impacts on the project infrastructure. Additionally, the project is designed to increase the resilience of the City to climate change and disasters. Therefore, all infrastructure is intended to be climate change proof and where vulnerabilities were identified, all of the necessary adaptions are incorporated into the design.

4. Maladaptation risks associated with proposed adaptation measures

138. Maladaptation refers to situations where climate funding or development funding may support initiatives that would negatively affect exposure and/or the sensitivity of society and ecosystems to climate-related stressors. It is driven by neglect of either the future impacts of climate change or the main drivers of the system's vulnerability. Maladaptation to climate change is a relatively recent consideration in development and there are a number of ways to measure maladaptation. It should be noted that maladaptation is relative, as the balance of the positive and negative effects of the initiative itself must be compared to the effects of other broader scale national and local adaptation and mitigation initiatives.

139. One important form of maladaptation is committing the MA to expensive solutions that do not adequately confer resilience to the community. One potential cause of this type of maladaptation is where the proposed adaptations are insufficient for the projected climate change impacts, requiring expensive retrofits of larger or more suitable infrastructure. In order to reduce the likelihood of this, it is advisable to adequately cater to impacts within the likely range of projected climate change. However, as this project is made up of short-, medium- and long-term phases, there is the capacity to re-assess the performance of infrastructure and make adjustments for later phases. By designing infrastructure to cater to the most likely projected climate change for the near or medium term, and reassessing infrastructure for the long term, there is no need to commit to the largest sized infrastructure possible. Additionally, the largest size for drainage infrastructure could be achieved while minimizing the relocation of households. The drainage plan in phase 1 is focused on improving drainage for the most urbanized areas, with drainage lines proposed for less urbanized areas at the medium phase. The long-term plan includes a review of the performance of phase 1 and 2 infrastructure, allowing for adjustments in the layout or sizing of any new infrastructure.

140. The proposed open channel drainage lines are similar to the existing canals that can be widened in the future if necessary. The WWTP is also designed with a staged approach and a review is proposed in the long term (2030-2040). At this stage, the amount of wastewater that needs to be treated will be reassessed, and the ability of the WWTP storm water management system to cater to extreme rainfall events can be assessed and redesigned based on the most up to date climate change projections. The solid waste landfill is proposed to be developed as a series of cells to be constructed at various stages with the function of each cell and ability to cope with leachate and rainfall quantities to assessed before the final design and construction of the next.

141. The same maladaptation of committing the MA to expensive inadequate infrastructure can be caused by committing to the installation of oversized infrastructure that results in higher construction and maintenance costs. In designing drainage for a city that is located on very flat terrain, one difficulty is allowing for enough fall to generate gravity flow and developing adequate drainage cross sectional area to cater to projected water volumes. Vulnerability analysis carried out during the design of the drainage for Bavet indicated that to cater to an increase in rainfall of 5% would require drains to be 20% larger, with an ever-increasing size needed for higher design rainfalls.

142. In many cities the higher standard for urban drainage pipes and channels of 1 in 5 year design is now used and it is considered an affordable balance between drainage infrastructure costs and reduced flood damage. Therefore, and as recommended in the national Road Design Standard (MPWT, 2003), the master plan recommended that the urban drainage of the city be design for a capacity for 1 in 5 year storm runoff. The use of the average of the outputs from an ensemble of climate change models has been shown to more adequately reproduce baseline climate statistics. Additionally, RCP8.5 is generally used as the business as usual case and RCP4.5 as the best case. Therefore, the current IDF curves are adjusted by 5% based the median extreme rainfall projected for 2040 from an ensemble of GCMs modelling RCP8.5.

143. The staged approach gives urban designers the chance to assess the performance of stage 1 infrastructure that has been designed to deal with a 1 in 5 year rainfall adjusted by 5% to allow for projected climate change. Additionally, the impacts of the new drainage infrastructure on reducing localized flooding can be assessed across the urban center. During the review phase, adjustments to the design can be made to respond to any climate trends and to new understanding of projected climate changes based on the most recent climate change science that is available at the time.

144. Potential maladaptation related to each project component are summarized in Table 22.

Table 22: Potential Maladaptation Measures for Each Project Component.

Component	Possible Maladaptation	Comment
Wastewater	May commit capital and institutions to trajectories that are difficult to change in the future	Design of proposed site taking into account planning for staged increase in capacity with review. Planned comprehensive sewage increases resilience and has positive CO_2 balance.
Stormwater	Insufficient for extreme events in the future	Design incorporates projected future extreme rainfall for the high CO_2 RCP8.5 scenario for 2040
	Over designed infrastructure committing MA to high financial burden	Design of proposed infrastructure taking into account planning for staged implementation with review.
Solid Waste	May commit capital and institutions to trajectories that are difficult to change in the future	Planned comprehensive waste management and recycling increases resilience and has positive CO_2 balance. LFG wells and collection infrastructure are designed with simple flue with the ability to move to power generation as institutional capacity increases.
	Insufficient for extreme events in the future	Ensuring proper drainage system at the landfill area including the increase of rainfall event by 5%
	Provision of disposal site catering to the business-as-usual habit of waste generation could inhibit the goal of waste minimization.	Provision of engineered sanitary landfill to address the problem of solid waste, recycling facilities and MFRs will provide a demonstration of best practice

5. Climate change adaptation costs

5.1. Direct costs

145. The cost of climate proofing the project components are presented in Table 23. The vulnerability analysis carried out during the master plan stage determined the potential cost of incorporating climate change adaptations. This analysis determined that to allow for an increase in extreme rainfall events of 5%, the average pipe/channel section would need to be increased by 20%. This increased the construction cost by 11% and this figure was used to determine extra costs to all drainage components of the infrastructure proposed for the feasibility stage. It should be noted that there have been substantial changes to stormwater infrastructure between the master plan and feasibility stages, however it is expected that the figure of 11% is still representative of the expected increase in cost for all drainage infrastructure. The total cost for the proposed adaptations is $1,036,482.

Table 23: Proposed Adaptation Measures and Costs for Each Project Component

Infrastructure Component	Proposed Adaptation Measures	Target Climate Risk	Estimated Adaptation Costs ($)
Wastewater	1 m added to height of dykes used within the WWTP	Extreme rainfall 5% larger Increased depth of flooding	8% increase in CAPEX $423,000
Stormwater	Increase size of drainage network	Increase of size if extreme rainfall event	11% increase in CAPEX $600,483
Solid Waste	Increase capacity of stormwater management system	Increase of size if extreme rainfall event	11% increase in CAPEX for drainage $12,999

5.2. Proportional costs

146. In many cases the proposed infrastructure is itself a climate change adaptation. As shown in section VI.1 above, the project contributes to Cambodia's international commitments and supports Priority Outcomes of the Cambodia Climate Change Strategic Plan 2014 – 2023. Improvements to the infrastructure to reduce the amount and length of localized flooding is a primary adaptation option to cope with the projected increase in localized flooding. Improving flood management will reduce standing water and reduce health impacts. The project will also produce flow on benefits of improvements to the functioning of all of the other urban infrastructure in the City. Successful completion of this project will increase resilience by reducing flooding in Bavet, but the proposed modifications to existing infrastructure are required now to reduce the flooding that currently occurs after heavy rain. Moreover, the options suggested for reducing the impact of higher intensity rainfall events on existing storm water drainage infrastructure, should be standard operating procedure for a good maintenance program. However, the improved

connectivity of the drainage system and increased capacity of MA staff in planning and maintenance will improve the resilience of Bavet and a proportion of the costs can be considered to contribute to climate change adaptation.

147. The provision of a wastewater treatment plant and associated pipe works, and pumping stations will decrease the sensitivity of Bavet city and improve the ability of households to recover, by decreasing the number of households exposed to wastewater during localized flooding events. However, the planning and provision of adequate wastewater service should be part of any city's infrastructure. Similarly, the provision of solid waste management infrastructure should be expected to be part of urban infrastructure. But the design and construction of a landfill that is climate change resilient is an important a climate change adaptation. The apportionment of costs of project infrastructure to climate change is presented in Table 24. As discussed above, the provision of adequate drainage system is an important adaptation so 30% of the cost are considered to be climate change adaptation. The provision of properly treated wastewater and solid waste management infrastructure are considered a municipal responsibility, but by ensuring it is planned and by incorporating phased revisions and implementation, 30% of the costs are considered to contribute to climate change adaptation. The inclusion of the composting facility contributes to the cities GHG commitments so considered to be a climate change mitigation and not included in the calculation. The total cost of proportional adaptation is $10,531,814.

Table 24: Proportion of Each Activity Related to Climate Change and the Proportional Cost Towards Adaptation

Activity	Result	Proportion	Costs ($)
Stormwater			
Rehabilitation and expansion of the drainage system to improve connectivity and increase the efficiency of the system	Decrease the exposure of the City to flood hazards by reducing blockages	30%	$1,131,806
	Minimize flood damage through efficient and quick removal of floodwaters		
	Decrease the sensitivity of the community by reducing negative health impacts		
Construction of well-designed outlets	Minimize flood damage through efficient and quick removal of floodwaters Decrease the sensitivity of the community by reducing negative health impacts		
Provision of green spaces around the existing water bodies	Improve infiltration into groundwater, improve air quality and will contribute to mitigation		

Activity	Result	Proportion	Costs ($)
Capacity building to use specialized equipment and to develop and carry out a maintenance program	This will make an immediate improvement to drainage functioning and will become progressively more important as heavy rainfall events become more likely		
Wastewater			
Provision of properly treated wastewater	Decrease the sensitivity of the City and improve the ability of households to recover, by decreasing the number of households exposed to wastewater during localized flooding events	30%	$7,961,922
Solid Waste Management			
Proper management and disposal of solid waste in landfill	Increase the resilience of the population by improving the health and wellbeing by reducing exposure to unhealthy waste	30%	$1,438,087
	Minimize health risks due to exposure during both flood events and drought		
Removing waste blocking the drainage system	Decrease the extent and length of flood events		

VII. MITIGATION

1. Contribution of project components to climate change

148. The project will contribute to CO_2 emissions as infrastructure materials are made, transported, and installed. The operation of pumping stations for sewage collection, wastewater treatment and the treatment of solid waste will also contribute to CO_2 emissions. The transport of the SWPT leachate to the WWTP will also contribute to CO_2 emissions. The compost process uses diesel fuel to manage the piles and transport materials. However, professionally managed treatment of wastewater and solid waste and the focus on recycling, LFG collection and development of a composting facility will all reduce emissions of N_2O and CH_4. Improved functioning of the Cities drainage network will reduce GHG emissions from stagnant water due to improved flows and connectivity. Additionally, the cost of the emissions needs to be counterbalanced by the contributions of the project towards international commitments; Sustainable Development Goals through the Rectangular Strategy - Phase 4 Strategic Goals, to Paris Agreement targets through the Cambodia Climate Change Strategic Plan 2014 - 2023 Priority Outcomes, and to the Sendai Framework commitments through the Strategic National Action Plan for Disaster Risk Reduction 2008 – 2013 Priority Area Objectives.

2. Proposed climate change mitigation measures

149. The Cambodian Government has a number of national strategies to reduce greenhouse gas emissions, and where possible these will be incorporated into the project. Some of the project components also contribute to lowering greenhouse gas emissions. The CCCSP has a strategic objective to promote low-carbon planning and technologies to support sustainable development. This includes the use of more sustainable urban transport options and tree planting in public spaces[41]. General mitigation strategies will be used as part of the overall project strategy where possible such as the use of biofuels, light vehicle technologies, electric vehicles. The project will contribute to mitigation by promoting the use of solar operation at the infrastructure site.

150. The waste management project components, including LFG collection with a flare stack, composting of organic waste; controlled wastewater treatment; recycling and waste minimization are greenhouse gas emission reduction strategies. In particular emissions of the more potent greenhouse gases Methane (CH_4) and Nitrous oxide (N_2O) from anaerobic decomposition will be reduced. Emissions of CO_2 and pollutants from burning rubbish will be reduced. Trees that are planted as part of the development will act as a CO_2 sink.

151. Mitigation options for specific infrastructure components are developed below.

Wastewater

152. The equipment and utilities to be used in the WWTP will be energy efficient such as LED lights, high EER rating air conditioning units, machines, and others to ensure minimum electricity/power consumption. The power requirement for the utilities including building, lighting,

---

[41] Ministry of Environment. 2016. Climate Change Action Plan 2016-2018. Ministry of Environment. Phnom Penh, Cambodia

automatic valves, lift system, and air conditioning including process cooling production for air blower is 78,701 kWh annually.

153. Solar power through the use of photovoltaic modules will be used to complement the WWTP building power requirement. The photovoltaic modules will be placed on a metallic structure near the buildings in the WWTP. The solar power is a 180 kWp system with a capacity to produce a total of 157,680 kWh annually. Due to the shift between solar radiation hours and WWTP energy need, only 61% of the power needs of the WWTP. At this stage, the surplus photovoltaic electricity is not considered to be resold to Electricité Du Cambodge (EDC). However, further negotiations with EDC could provide a new source of revenue for the operator and reduce the burden of electricity consumption. The cost of implementation (panels supply, installation, and metallic structure) is $297,000.

Solid Waste

154. The equipment and utilities to be used in the sanitary landfill will be energy efficient such as LED lights, high EER rating air conditioning units, machines, and others to ensure minimum electricity/power consumption. The power requirements for the utilities including building, lighting and air conditioning including process cooling production for air blower is 83,380 kWh annually. Leachate disposal equipment at the landfill requires an annual power of 10,950 kWh (Flare stack 8,760 kWh and Recirculation pump 2,190 kWh). At this stage the use of low emission trucks is not an option due to the high cost and lack of hydrogen infrastructure needed for the high power consumption for compactors.

155. Solar power through the use of photovoltaic modules could be used to complement the power requirements of the landfill building and leachate disposal. The photovoltaic modules will be placed on a metallic structure near the facilities of the new landfill. The solar power is a 110 kWp system with a capacity to produce a total of 100,200 kWh annually. Due to the shift between solar radiation hours and energy need, only 69% of the power needs of the Landfill non-process equipment (i.e., 60,000 kWh annually) and 77% of Leachate disposal (i.e., 15,150kWh annually) will be met by local solar production with the rest to be purchased from the electric grid, producing an estimated saving of US$9,119 annually. At this stage, the surplus photovoltaic electricity is not considered to be resold to Electricité Du Cambodge (EDC). However, further negotiations with EDC could provide a new source of revenue for the operator and reduce the burden of electricity consumption.

156. Two further measures to reduce GHG emissions are integrated into the project;

157. **LFG capture.** The sanitary landfill will have an LFG management system with LFG wells in the waste mass and a flare stack for direct combustion of the LFG. It is estimated that by 2040 up to 150 m^3 of methane will be captured from the landfill per hour. In the initial stage of the project it is recommended that active venting with a flare stack be used for ease of operation with a view to installing electricity installation in the future. Both of these options will convert methane into CO_2. As methane produces 28 times more greenhouse warming than CO_2, the conversion of the estimated N_2O emissions to CO_2 equates to a reduction in greenhouse potential of 25,811 kg CO_2e.

158. **Composting Plant.** There are currently no existing composting options at the landfill. The design at the new SWM includes a windrow composting plant using green waste from parks and gardens that are shredded and mixed up with biowaste from markets. Well run composters emit little methane and N_2O, hence, this is part of the high methane generation potential part of the MSW which will not be landfilled and will be treated in such a way as to achieve almost 100% degradation with minimal extra atmospheric GHG emissions. Additionally, the use of the compost will contribute to carbon sequestration. It is difficult to calculate the CO_2 emission reductions until the exact design and size of the composting plant and the makeup and moisture content of the feedstock is determined but it is estimated that 2572 t/y of material will be composted by 2025 saving conservatively around 2,500 kg of CO_2e[42].

3. Prioritization of measures

159. All measures that are financially feasible will be incorporated.

4. Climate change mitigation costs

160. The cost of climate change mitigation incorporated into the project components are presented in Table 25. As the composting plant reduces emission of the more potent GHGs methane and nitrous oxide it can be considered a mitigation. Similarly, the LFG flue converts methane and nitrous oxide to CO_2 and reducing overall GHG emissions. The total cost for the proposed mitigations is $2,526,789.

Table 25: Proposed Mitigation Measures and Costs for Each Project Component

Infrastructure Component	Proposed Mitigation Measures	Estimated avoided GHG Emissions	Estimated Mitigation Costs ($)
Wastewater	Use of solar power thru PV modules	37,353 kg CO_2e/yr	$297,000
Solid Waste	LFG collection and flue	25,811 kg CO_2e/yr	$212,943
	Composting Plant	2,975 – 4,630 kg CO_2e/yr	$1,835,346
	Use of solar power thru PV modules	8,398 kg CO_2e/yr	$181,500

[42] Based on conversion rate presented in Biala, J. 2011. *The benefits of using compost for mitigating climate change.* Department of Environment, Climate Change and Water NSW. Sydney.

APPENDICES

Appendix 1. Adaptive Capacity Assessment Table

1. The capacity of the local government and the local community to adapt to each hazard is assessed using the following table:

Factor	Adaptive Capacity Level/Score				
	High (5)	Medium High (4)	Medium (3)	Medium Low (2)	Low (1)
Economic Wealth	▪ Have adequate and available financial resources for assistance to all affected sector ▪ The people in the affected areas have their own resources to respond to a hazard	▪ Have enough financial resources for assistance to some affected sectors ▪ The people in the area have access to resources to respond to a hazard	▪ With limited financial resources for assistance for priority affected sectors ▪ The people in the area have limited access to resources to respond to a hazard	▪ Have limited financial resources for assistance to affected sectors ▪ Affected people have very limited access to resources to respond to a hazard	▪ No available financial resources for assistance to affected sector ▪ Affected people don't have their own resources to respond to a hazard
Technology	▪ There are equipment available for use and facilities to communicate directly with the people/sector affected	▪ There are some equipment available for use and facilities to communicate directly with the people/sector affected	▪ Limited equipment and facilities for assistance and communication	▪ Very limited equipment and facilities for assistance	▪ Very few equipment and facilities for use and communication with affected people/sector is difficult
Institutional	▪ MA and community leaders are aware and could effectively manage a quick response in the event of a hazard occurrence ▪ There are existing processes and regulations to control the situation ▪ Relevant legislations are in place to	▪ MA and community leaders are aware and can response in the event of a hazard occurrence ▪ There are processes and regulations but not yet fully implemented nor tested	▪ MA and community leaders are aware but management set-up to respond to a hazard is non-existent. ▪ Relevant processes, procedures and legislations are passed but implementing guidelines still has to be formulate	▪ Few MA officials and leaders are aware of the roles and functions during but quick response team to quickly respond during an occurrence of a hazard is yet to be formed ▪ Draft process, procedures and relevant legislations still has to be passed	▪ MA officials are not fully aware of a hazard or disaster that may occur ▪ There are no definite processes and regulations to control the situation and respond to a certain hazard.

Factor	Adaptive Capacity Level/Score				
	High (5)	Medium High (4)	Medium (3)	Medium Low (2)	Low (1)
	respond to a certain hazard				
Infrastructure	▪ There is more than adequate transport, water infrastructure, sanitation, energy supply and management and medical services that can be used to respond to a hazard ▪ These facilities and infrastructures are strong enough to withstand a projected hazard and located in safe areas	▪ There is enough transport, water infrastructure, energy supply and medical service, etc. that can be used to respond to a hazard ▪ Facilities and equipment are available but not enough	▪ There are some infrastructure, transport facilities and necessary equipment that can be used to respond to a hazard but not enough to accommodate a projected impact of a hazard ▪ Infrastructure and facilities still has to be retrofitted to ensure its safety and strength during a hazard	▪ Infrastructures are available but there are no facilities that can be used to respond to a hazard ▪ Transport services in some possibly affected areas are not available	▪ Necessary infrastructures and facilities necessary to respond to a hazard still has to be constructed ▪ Existing infrastructures and facilities are not within standard to withstand a projected impact of a hazard
Information	▪ MA and stakeholders in the area/sector are well aware of the hazard and its potential impact to them ▪ Communication facilities and procedures are in place to respond in the occurrence of a hazard ▪ Early warning system in place and drills have been conducted	▪ MA and some stakeholders are aware of the hazard and its potential impact to them ▪ There is an early warning system in place	▪ Some degree of awareness of MA and stakeholders ▪ Communication facilities are in place but procedures are not yet in place ▪ Draft early warning system available	▪ Limited awareness of MAs and stakeholders due to lack of IEC program	▪ MA officials and affected communities are not yet fully aware of the hazards and its potential impact ▪ No early warning system yet
Social Capital	▪ There is political willingness to allocate resources to build adaptive capacity of the MA	▪ There is some degree of willingness of the leaders to allocate funds to build	▪ MA have political willingness but still has to be convinced to allocate resources to build	▪ MA officials still has to be convinced to allocate resources to build adaptive capacity of MAs	▪ MA officials still has to be oriented on adaptive capacity building

Factor	Adaptive Capacity Level/Score				
	High (5)	**Medium High (4)**	**Medium (3)**	**Medium Low (2)**	**Low (1)**
	▪ There are specific agencies, community groups and/or NGOs that have the mandate and skills to focus on the specific sector/area during occurrence of hazards ▪ There are trained emergency response teams for this sector/ area	adaptive capacity of the MA ▪ Some agencies are and NGOs are available and have skills to assist specific sectors during occurrence of hazard ▪ There is a team with basic skills for emergency response	adaptive capacity of MAs ▪ There are specific agencies and NGOs with mandate to assist affected communities but still lack skills to respond ▪ Team have been organized for emergency response	▪ There are limited number of agencies and NGOs with mandate and skills to assists occurrence of hazards ▪ Team for emergency response still to be organized	▪ Specific agencies still has to have clear mandate and plans to assist affected communities ▪ No NGOs with mandate and skills to help specific sector in times of climate hazards ▪ No policies or orders yet for the creation of the team for emergency response

Source: Egis, 2021.

Appendix 2. Table of Likelihood Descriptors

Category	Description	Expectance	Recurrence Interval	Probability
L6	Certain	Expected to occur in most circumstances.	Expected to occur several times per year.	Has a greater than 90% chance of occurring in a year.
L5	Very Likely	Will probably occur in most circumstances.	Will probably occur about once per year.	Has a 60–90% chance of occurring in a year.
L4	Likely	Will probably occur at some time	Will probably arise once in 5 years	Has a 40–60% chance of occurring in 5 years.
L3	Possible	May occur at some time.	May arise once in 10 years	Has a 20–40% chance of occurring in 10 years.
L2	Unlikely	May occur at some time but is considered unlikely.	May arise once in 10 to 20 years.	Has a 10–20% chance of occurring in the future.
L1	Rare	Could occur in exceptional circumstances.	Unlikely during the next 20 years.	Could occur in exceptional circumstances (i.e. less than 10% chance of occurring by 2040).

Appendix 3. Descriptors of Consequence Table

1. In the second step of the risk calculation, the level of the impact (consequence) on the land, built environment and people for each hazard scenario is assessed. The assessment is formed from a combination of inputs; the GIS analysis showing the number of km or the number of components that are exposed, the estimate of the degree of impact, the sensitivity analysis, and the adaptive capacity assessment. The assessment is informed by questions such as:

a) Is the effect of the hazard a brief inconvenience (e.g., road flooding) or high cost (e.g., flooding of many houses, or several days inundation)?

b) Are assets easily relocatable (e.g., concrete slab-on-ground houses, is there access to alternative sites).

c) Are there particular environmental issues to be considered (e.g., undermining of septic tanks or erosion or waterlogging of effluent disposal fields, causing water pollution)?

d) Are there particular social issues that need to be considered (e.g., housing occupied by people who have limited ability to recover from financial losses, or cultural ties and rights to an area)?

e) Is the effect of the hazard continuous (e.g., coastal erosion) or intermittent (e.g., flooding)?

2. The consequences are then categorized using the Descriptors of Consequence Table presented below.

Consequence	Category	Description
C6	Extreme	Major irreversible impact requiring complete replacement.
C5	Major	Significant impact, long term, requiring substantial repair/replacement of long sections/whole components.
C4	Severe	Strong impacts, requiring substantial repair/replacement of some sections/components.
C3	Moderate	Low-Medium impacts, requiring repairs to some whole sections/components of infrastructure.
C2	Minor	Low impact, localized repairs to short sections/components
C1	Negligible	Insignificant impact, minor repairs to small sections