Mekong River Commission

THE INITIAL STUDIES PROJECT

INITIAL STUDIES TO DEMONSTRATE THE FORMULATION OF STRATEGIC DIRECTIONS TO MANAGE EXISTING, FUTURE & RESIDUAL FLOOD RISKS IN THE LOWER MEKONG BASIN

FLOOD MITIGATION AND MANAGEMENT

Task 7/B

"STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT"

NAM MAE KOK BASIN (NMK), THAILAND

DRAFT REPORT

2018

EXECUTIVE SUMMARY

This report shows the work under Task7 of the 'Initial Studies' Project which has been designed to deliver Outputs 1.2 and 2.4 of FMMP 2011-2015, namely:

Output 1.2 Demonstration of the formulation of Integrated Flood Risk Management (IFRM) Plans and Strategic Directions to manage future and residual flood risks, including the impacts of possible future climate change, for the Nam Mae Kok Basin (NMK) of Thailand.

Output 2.4 Impact of climate change on short and long-term flood behavior and forecasting and climate change adaptation are systemized in the RFMMC and Member Countries.

In addition to climate change, upstream developments (dams) and future changes to the Basin's floodplains will affect flood behavior and flood risk in the Lower Mekong Basin. Future floodplain changes include the development of new infrastructure, increased population, changes to land-use, a higher standard of living, etc. The Initial Studies address the impacts of all these factors on future flood behavior and flood risk in the Lower Mekong Basin.

To provide technical inputs, assess and formulate issues for Nam Mae Kok basin floodplain in Thailand to implement the Tasks of Initial Studies Stage-2. as follow;

1. Task 4: Assessment of possible future flood behavior under conditions of inferred future climate change, future upstream developments (dams) and future floodplain development.

2. Task 5: Formulation of existing and future flood damage estimation relationships.

3. Task 6: Assessment of existing and future flood event damage and average annual damage.

4. Task 7: Delivery of pilot studies to demonstrate the formulation of strategic directions to manage existing, future and residual flood risks in the three FFAs, including indicative IFRM Plans.

Task 7 in this report requires outputs from task4, 5 and 6.

Base on Initial Study phase I, the station at the Lao River crossing with the Road no. 1020 was selected for this study as it experiences representative flooding characteristics at Mueang Chiang Rai District. Similarly, a station of the Kok River near Wat Santhat Asoka Ram Temple in Chiang Saen District, 11 km upstream from the river mouth is chosen for representing flooding condition of the Chiang Saen District.

Based on conceptual and result from Task 3 report (MRC, 2016) and national sector report, it was identified for land use, infrastructure, agricultural and projection future development in NMK. Therefore, Floodplain scenarios were designed based on suggestion from NTWG – TNMC as describe below:

- Upstream development (USD) and floodplain development (FPD)
- Climate change
- New proposed water infrastructure

Description of scenario under Upstream development and floodplain development is as follow:

(1) BDS0-Baseline 2014:

Scenarios on existing flood behavior and development in 2014 (Baseline condition). BDS0 refer to situation in year 2014 that have completed flood protection projected in Chiang Rai city composed of (1) Nam Korn – Nam Mae Kok Diversion canal (2) Rehabilitation of existing weirs on Nam Korn (3) Nam Korn and Nam Lao embankment improvement. Land use for BDS-BL2014 will base on current situation year 2014 and current existing structure and floodplain condition

(2) BDS1-2020:

Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 25% flood storage over the NMK and definite development in 2020.

(3) BDS2- 2040:

Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 50% flood storage over the NMK and definite development in 2040.

(4) BDS3- 2060:

Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 75% flood storage over the NMK and definite development in 2060.

(5) BDS3a-2060Flw:

"BDS3a-2060Flw" means "BDS3-2060" with Floodway in Nam Korn – Nam Lao. Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 75% flood storage over the NMK and definite upstream development in 2060 plus new proposed floodway in Nam Korn –Nam Lao.

(6) BDS3b-2060Bnk:

"BDS3b-2060Bnk" means "BDS3-2060" with Bank Protection in Lower Nam Kok. Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 75% flood storage over the NMK and definite upstream development in 2060 plus new proposed river bank in Lower Nam Kok.

(7) BDS3c-2060CC:

"BDS3c-2060CC)" means "BDS3-2060" with Climate change. Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 75% flood storage over the NMK and definite upstream development in 2060 include impact from Climate Change.

(8) BDS3d-2060CCFlw:

"BDS3d-2060CCFlw" means "BDS3-2060" with Floodway in Nam Korn – Nam Lao and Climate change. Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 75% flood storage over the NMK and definite upstream development in 2060 plus new proposed floodway in Nam Korn –Nam Lao include impact from Climate Change.

(9) BDS3e-2060CCBnk:

"BDS3e-2060CCBnk" means "BDS3-2060" with Bank Protection in Lower Nam Kok and Climate change. Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 75% flood storage over the NMK and definite upstream development in 2060 plus new proposed river bank in Lower Nam Kok include impact from Climate Change.

Summary of physical scenario is presented as follow;

Scenario	**Year**				**USD&FPD (Loss of flood storage, %)**				**Climate Change**	**New proposed structure**	
	2014	2020	2040	2060	0	25	50	75		Flw	Bnk
BDS0-2014	O				O						
BDS1-2020		O				O					
BDS2-2040			O				O				
BDS3-2060				O				O			
BDS3cc-2060cc				O				O	O		
BDS3a-2060Flw				O				O		O	
BDS3b-2060Bnk				O				O			O
BDS3d-2060CCFlw				O				O	O	O	
BDS3e-2060CCBnk				O				O	O		O

In this study, not only physical scenario is applied, but economic scenario is also considered as follow;

(1) Scenario 1 Business as Usual (A1N1): Integration of [1] socio-economic scenario in agriculture “A1”: farmer uses technology and innovation for rice production; [2] socio-economic scenario in housing and infrastructure “HI1” under population and GDP per capita in the future.

(2) Scenario 2 Greater value-added Rice (A2N1): The same structure as scenario 1 but socio-economic scenario in agriculture “A2” means farmer use technology and innovation for rice production concentrated in organics way to increase value added of rice.

Damage curve and flood damage probability curve are calculated to illustrate existing and future flood damage estimation relationships in each previous developed scenario.

Existing and future flood event damage and average annual damage are also developed by using Average Annual Damage (AAD) and Net Present Value (NPV) of AAD for risk assessment in each physical scenario, each economic scenario, each sector and each area.

Pilot studies of new proposed structure are demonstrated the formulation of strategic directions to manage existing, future and residual flood risks in this area. Calculation results show that climate change provides greater flood risk and damage in the future. The impact of water-infrastructure is small compared to climate change. This causes by exiting flood mitigation system, backwater effect from Mekong River and locations. Climate change seem to be majority of flood damage, especially in the far future (year 2060).

RECOMMENDATIONS

Recommendations can be shown as follow:

(1) Policy makers should carefully consider how to address the future flood risk in both structural measures and non-structural options.
(2) Citizen participation in flood risk reduction should be considered.
(3) Information and technology should be shared among all related local agencies in flood prevention and mitigation in regional and local levels.
(4) Capacity building to the planning and operational staffs to flood should be strengthened. In addition, encouragement of persons in charge of monitoring and communication is recommended.
(5) Communication between line agency and local people should be carefully considered and developed.
(6) Legal and institutional arrangement for flood risk reduction should be transformed for local community to easily implement.

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AAD	Average Annual Damage
BaU	Business as Usual
C2	Component 2 of the Floodplain Management and Mitigation Program studies 2006-2010
CC	Climate Change
DDPM	Department of Disaster Prevention and Mitigation
DSF	Decision Support Framework
DWR	Department of Water Resources
FFA	Flood Focal Area
FIP	Future Impact Period (24 years duration)
FLFA	Flood Level Frequency Damage
FPDs	Future Floodplain developments
FMMP	Flood Management and Mitigation Programme
IAT	Impact Analysis Tool
IAL	Impact Assessment Location (representative node in hydrodynamic model)
IS	Initial Studies
IFRM	Integrated Flood Risk Management
IKMP	Information and Knowledge Management Programme
IQQM	Integrated Quantity and Quality Model
ISIS	Name of the Hydrodynamic Model
LMB	Lower Mekong Basin
LU	Land Use
MC	Member Countries, viz. Cambodia, Lao P.D.R, Thailand and Viet Nam
MRC	Mekong River Commission
NMK	Nam Mae Kok River Basin
NPV	Net Present Value
RID	Royal Irrigation Department
RFMMC	Regional Flood Mitigation and Management Center
S-E	Socio-Economic
TB	Transboundary
TMD	Thai Meteorological Department
TNMC	Thai National Mekong Committee
TNMCS	Thai National Mekong Committee Secretariat
USDs	Future Upstream developments
WUP	Water Utilization Program of the MRC

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The Mekong River Commission (MRC) was established by the 1995 Agreement on Cooperation for the Sustainable Development of the Mekong River Basin, between the Governments of Cambodia, Lao PDR, Thailand and Viet Nam. In accordance with the Agreement, the Mission of MRC is "to promote and coordinate sustainable management and development of water and related resources for the countries' mutual benefit and the people's well-being by implementing strategic programmes and activities and providing scientific information and policy advice."

FLOOD MANAGEMENT AND MITIGATION PROGRAMME (FMMP) 2011-2015

All MRC Programmes developed their programme documents for the period 2011-2015 in line with the goals of the MRC Strategic Plan for this period. Flood Management and Mitigation Programme (FMMP) was one of the twelve MRC programmes and, since 2012, had developed particularly strong ties with the Climate Change and Adaptation Initiative (CCAI), the Information and Knowledge Management Programme (IKMP) and the Basin Development Programme (BDP), while links had become increasingly stronger with the Integrated Capacity Building Programme (ICBP) and the Drought Management Programme (DMP). FMMP was also in close contact with the Mekong Integrated Water Resources Management Project (Mekong-IWRM-P), while interaction with the Navigation Programme (NAP), the Environment Programme (EP), the Agriculture and Irrigation Management Programme (AIP), the Fisheries Programme (FP) and the Sustainable Hydropower Initiative (ISH) had been more of a more ad-hoc character. The linkages between FMMP and other MRC Programmes were well identified.

Flood Management and Mitigation (FMM) represented one of the MRC priorities, as reflected in the MRC Strategic Plan 2011-2015. The MRC will continue to support the MRC Member Countries in this field of flood management and mitigation through FMMP 2011-2015, which followed on from FMMP 2004-2010. The Programme Document for FMMP 2011-2015 (Volume 1: main report and Volume 2: annexes) was adopted by the 33rd meeting of the

MRC Joint Committee on 25-26 March 2011 and served as an important MRC reference document.

FMM TEAM UNDER MRCS 2016-2020

It was agreed with the MRC Member Countries that with the available means in 2015 the Initial Studies could not be completed. It was agreed that FMMP 2011-2015 would request Development Partners to make "earmarked" funding available to complete the Initial Studies. In January 2016 it became clear that The Government of The Netherlands would be willing to consider additional funding to complete the Initial Studies. A final decision was taken by December 2016. Since 1st January 2016 the new organizational structure of MRCS has been adopted, merging FMM disciplines into one (Technical Support Division – TD) of the 4 Divisions of the new structure.

THE INITIAL STUDIES

An important component of FMMP 2011-2015 is the 'Initial Studies' Project, which has been designed to deliver Outputs 1.2, 2.4 and 3.2 of FMMP 2011-2015, namely:

Output 1.2 Demonstration of the formulation of Integrated Flood Risk Management (IFRM) Plans and Strategic Directions to manage future and residual flood risks, including the impacts of possible future climate change, for the Nam Mae Kok Basin (NMK) of Thailand and the Xe Bang Fai Basin of Lao PDR.

Output 2.4 Impact of climate change on short and long-term flood behavior and forecasting and climate change adaptation are systemized in the RFMMC and Member Countries.

Output 3.2 Demonstration of the formulation of an IFRM Plan and Strategic Directions to manage future and residual flood risks, including the impacts of possible future climate change and sea level rise, across the trans-boundary floodplains of Cambodia and Viet Nam's Cuu Long Delta (joint project).

In addition to climate change, upstream developments (dams) and future changes to the Basin's floodplains will affect flood behavior and flood risk in the Lower Mekong Basin. Future floodplain changes include the development of new infrastructure, increased population, changes to land-use, a higher standard of living, etc. The Initial Studies address the impacts of all these factors on future flood behavior and flood risk in the Lower Mekong Basin.

The Initial Studies build upon work and results obtained under FMPP 2004-2010 for the three flood focal areas (FFAs) described in Outputs 1.2 and 3.2 above. Eight tasks to deliver the above outputs are listed below, which was accepted by the FMMP's 26th Programme Coordination Committee meeting, conducted in Hanoi, Viet Nam on 28 May 2015.

Task 1	Simulation and assessment of existing flood behavior and possible future flood behavior under climate change across the LMB and in the three FFAs and their hotspots.
Task 2	Delivery of Pilot Projects to identify and implement non-structural climate change adaptation measures, including indicative IFRM Plans.
Task 3	Formulation of future floodplain development scenarios, embracing population growth, increase in standard of living, changes to land-use and new floodplain infrastructure developments.
Task 4	Assessment of possible future flood behavior under conditions of inferred future climate change, future upstream developments (dams) and future floodplain development.
Task 5	Formulation of existing and future flood damage estimation relationships.
Task 6	Assessment of existing and future flood event damage and average annual damage.
Task 7	Delivery of pilot studies to demonstrate the formulation of strategic directions to manage existing, future and residual flood risks in the three FFAs, including indicative IFRM Plans.

Remarks: In this study, Flood Focal Areas (FFAs) is Nam Mae Kok (NMK) basin floodplain in Thailand.

1.2 OBJECTIVE

To provide technical inputs, assess and formulate issues for Nam Mae Kok basin floodplain in Thailand to implement the Tasks of Initial Studies Stage-2. as follow;

1. Task 4: Assessment of possible future flood behavior under conditions of inferred future climate change, future upstream developments (dams) and future floodplain development.
2. Task 5: Formulation of existing and future flood damage estimation relationships.

3. Task 6: Assessment of existing and future flood event damage and average annual damage.
4. Task 7: Delivery of pilot studies to demonstrate the formulation of strategic directions to manage existing, future and residual flood risks in the three FFAs, including indicative IFRM Plans.

1.3 STRUCTURE OF REPORT

This report consists of five main chapters as follow;

Chapter 1 Introduction with the details of background and objective;

Chapter 2 Summary of work carried out to date Task 5A & 6A with the calculation results of flood damage, flood level frequency curve, damage probability curve and annual average damage in baseline case (BL2014) and 6 climate change scenarios;

Chapter 3 Description of possible future flood behavior under conditions of inferred future climate change, future upstream developments (dams) and future floodplain development is assessed by scenario-based approach;

Chapter 4 Flood damage curve and flood damage probability curve are calculated to illustrate existing and future flood damage estimation relationships in each developed scenario;

Chapter 5 Existing and future flood event damage and average annual damage are also developed by using Average Annual Damage (AAD) and Net Present Value (NPV) of AAD for risk assessment in each physical scenario, each economic scenario, each sector and each area;

Chapter 6 Pilot studies of new proposed structure are demonstrated the formulation of strategic directions to manage existing, future and residual flood risks in this area;

Chapter 7 Conclusion and recommendations

CHAPTER 2

KEY FINDINGS OF PREVIOUS WORK

2.1 EXECUTIVE SUMMARY

Sompong (2015) analyzed and summarized calculation results for of Task 5a and 6a of the Initial Study (IS) which is part of the MRC Council Study (CS), aiming to analyses flood damages under baseline year of 2014 and future years with climate change (CC) (years 2030, 2060 and 2090). The study areas are namely Mueang Chiang Rai and Chiang Saen Districts of Chiang Rai province, northern part of Thailand. The two districts are in the Mae Kok River Basin, a tributary basin of Mekong River. The annual district historical flood damage records by the Department of Disaster Prevention and Mitigation (DDPM) are collected and analyzed. All the damage values are concerted to US $ at 2014 price level for the analysis.

For the Mueang Chiang Rai and Chiang Saen District, the annual maximum flooding water levels for the year 2007-2014 are analyzed by mathematical modelling simulation which is carried out under the Task 1 of the IS. The station at the Lao River crossing with the Road no. 1020 (UTM grid; 47Q 588466 mE 2195837 mN) is selected for this study as it experiences representative flooding characteristics at Mueang Chiang Rai District. Similarly, a station of the Kok River near Wat Santhat Asoka Ram Temple (UTM grid; 47Q 613811 mE 2235162 mN) in Chiang Saen District, 11 km upstream from the river mouth is chosen for representing flooding condition of the Chiang Saen District.

It is found that the Mueang Chiang Rai district at present (2014) has the average annual flood damage (AAD) of 0.09 m$ (83% agriculture, 9.5% infrastructure and 7.5% housing) while the AAD of Chiang Saen district is 0.04 m$ (94.5% agriculture,5.4% infrastructure and 0.1% housing). The AAD values found are rather small due to the fact that flooding occurs in low lying and depression areas which are marginal lands or used as rice fields with having rather low value product. The high value crops are grown on higher ground and free from flooding. Under future with climate change condition, the CC effects are progressive. Comparing with 2014, the AAD value can be double in 2060 and 2.5 time or more in 2090.

In addition, the study also collects annual flood damage data for specified districts in the Mekong provinces of Thailand for next step CS of MRC. This is an important data for the main process in this report.

2.2 METHODOLOGY AND DELIVERABLES

Task 5a and 6a consist of 3 work packages;

WORK PACKAGE 1: FLOOD DAMAGE DATA COLLECTION FOR FMMP INITIAL STUDY

The consultant team together with relevant line agencies at central and local level jointly reviewed the available flood damage data and develop the preliminary flood damage data report

Key activities	Key outputs
1) Coordinate with relevant agencies responsible for flood damage data collection at central level and provincial level 2) Develop flood damage data collection and reporting format 3) Develop report on sample annual flood damage data for single district and single province 4) Conduct additional data collection and analysis based on the consultation with FMMP 5) Develop report on flood damage data for FMMP Initial Study	1) Report on sample annual flood damage data for single district and single province 2) Report on flood damage data for FMMP Initial Study – Nominated districts 3) Maps with flood areas in districts (flood prone areas, topography, village, main infrastructure, etc)

Source: (Sompong, 2015)

WORK PACKAGE 2: FLOOD DAMAGE DATA COLLECTION FOR MRC COUNCIL STUDY

Key activities	Key outputs
1) Coordinate with relevant agencies responsible for flood damage data collection at central level and provincial level. 2) Develop flood damage data collection and reporting format 3) Field flood damage data collection in key line ministries and provinces as identified in the MRC council study	1) Report on flood damage data for MRC Council Study

Key activities	Key outputs
4) Conduct additional data collection and analysis based on the consultation with FMMP 5) Develop report on flood damage data for MRC Council Study	

Source: (Sompong, 2015)

WORK PACKAGE 3: ANALYSIS OF FLOOD DAMAGE ESTIMATION RELATIONSHIP FOR FMMP INITIAL STUDIES

Based on the results from the flood data collection in FMMP initial studies – flood focal areas, the analysis for flood damage estimation relationship will be carried out

Key activities	Key outputs
1) Develop draft report on existing flood damage estimation in IS-districts in consultation with FMMP 2) Conduct consultation workshop with FMMP on the estimation of flood damage and average annual damage 3) Develop and finalize the report on flood damage estimation relationship 4) Finalize the report on existing flood damage estimation relationship 5) Conduct the analyses and draft report of existing annual flood damage and AAD in Baseline period and future annual flood damage and AAD for the CC situations 2030-2060-2090 6) Conduct the consultation workshop with FMMP on the estimation of existing and future flood damage estimation 7) Analyze and finalize the report on Existing Flood Damage and AAD in Baseline Period	1) Report on Existing Flood Damage Estimation 2) Report on Existing Flood Damage and AAD in Baseline Period and future annual flood damage and AAD for the CC situations 2030-2060-2090.

Key activities	Key outputs
and future annual flood damage and AAD for the CC situations 2030-2060-2090.	

Source: (Sompong, 2015)

CLIMATE CHANGE SCENARIOS

The climate change (CC) scenarios used in task 5a and 6a are as follows:

- CC_M 2030 (moderate CC in 2030)
- CC_M 2060 (moderate CC in 2060)
- CC_S 2060 (stronger CC in 2060)
- CC_E 2060 (extreme CC in 2060)
- CC_ D 2060 (Dry CC in 2060)
- CC_M 2090 (moderate CC in 2090)

2.3 KEY RESULTS

FLOOD DAMAGE DATA COLLECTION FOR FMMP INITIAL STUDY

Sompong (2015) collected the damage data are collected from the Department of Disaster Prevention and Mitigation (DDPM. The DDPM local staff are responsible for estimating damages by flooding soon after the flood has started. The amounts in monetary term are calculated based on the number of items, properties and the unit price in that year.

WATER LEVEL DATA

ISIS mathematical model is applied to calculate maximum daily water level in each year for the selected locations representing flood characteristics of the two chosen key districts in the Kok River Basin, i.e. Mueang Chiang Rai and Chiang Saen Districts.

The rainfall under Climate Change (CC) conditions are determined using the products supplied by CCAI of MRC. The ISIS is run for various CC cases (years 2030, 2060 and 2090) to determine annual maximum water levels. The plotting position method is applied to give maximum water levels corresponding to assumed return periods.

DAMAGE VS FLOOD WATER LEVEL

The damage data collected are then adjusted to be equivalent 2014 price by using Thailand Consumer Price Index. The damage and water level data are plotted to get relationship.

FLOOD LEVEL FREQUENCY CURVE

The annual maximum water level data is plotted with the return period or annual recurrence interval.

DAMAGE PROBABILITY CURVE AND ANNUAL AVERAGE DAMAGE

The damage data are analyzed using the relationship between the max water level and annual recurrence interval to determine the relationships between the damage and probability of exceedance for Mueang Chiang Rai and Chiang Saen Districts. Average annual damage (AAD) for each climate change scenario is also shown.

For Mueang Chiang Rai, average annual damage impacted from each climate change are 0.09, 0.13, 0.18 and 0.26 m$ respectively for the BL, CC2030, CC2060 and CC2090. For Chiang Saen, average annual damage impacted from each climate change are 0.04, 0.15, 0.17 and 0.09 m$ respectively for the BL, CC2030, CC2060 and CC2090. From the above results, the damages can be double or more in 2060 compared to 2014 with climate change impact.

2.4 CONCLUSION

In Task 5a and 6a of the Initial Study (IS), a number of key calculation results including (1) flood damage data, (2) water level data, (3) damage vs flood water level, (4) flood level frequency curve and (5) damage probability curve and annual average damage are analyzed under climate change scenarios. However, in this report, flood water level and economic damage will be updated, calculated and illustrated in the following chapters.

The next chapter will be analyzed under the same method as task 5a and 6a; however, the main difference is the new task is under socio- economic development in the future. In the future, policy maker has to make decision under uncertainty using scenario approach not only under climate change scenarios but also under development scenarios. A number of options is selected to mitigate flood damage under uncertainty in the future with these analyzed data.

CHAPTER 3

IMPACTS OF P-2060-P ON FUTURE FLOOD BEHAVIOR (TASK4)

3.1 INTRODUCTION

This chapter is related to task 4 "Assessment of possible future flood behavior under conditions of inferred future climate change, future upstream developments (dams) and future floodplain development." The main issue is future development based on scenario approach. In this report, Task 4B will be applied in Mueang Chiang Rai and Chiang Saen Districts in Chiang Rai province and in Nam Mae Kok or NMK sub-basin. Flood behavior under conditions of inferred future climate change is shown in chapter 2. Future upstream developments (dams) in this area is quite difficult to construct based on environmental and social issues in Thailand. In this chapter, development of study area from 2-time steps; (1) from the past to present and (2) development in the future as the "preferred future (2060) floodplain development scenario" in the NMK sub-basin floodplain & Flood Focal Area (FFA) compared to the baseline

3.2 STATUS OF NAM MAE KOK (NMK) SUB-BASIN FROM THE PAST TO PRESENT

PHYSICAL CONDITION

The Kok River or Nam Mae Kok (local name) Basin (**Figure 1**), a tributary basin of the Mekong River (Mekong River meanders along the Thai-Lao border), covers an area of 10,300 km^2. The length of the river from source to mouth is 320 km. The river begins in Myanmar and crosses the Thai border after 170 km near Ban Tha Ton. In Thailand the river is joined by the Nam Mae Fang near to Thai-Myanmar border, at Chiang Rai upstream of the Chiang Rai Weir by the small but for flooding important Nam Mae Korn, and just downstream of the weir by the largest tributary the Nam Mae Lao. From Chiang Rai to the river mouth a few smaller tributaries like the Mae Hang and Mae Phue join before the Kok drains into the Mekong at Sop Kok, some 5 km downstream of Chiang Saen gauging station at an elevation of 355 m MSL. The basin is mountainous on the divides with elevations up to 2,000 m. The highest peak of 2,285 m in height is Doi Pha Hom Pok, located in Fang district, Chiang Mai province. Most areas are under forest cover, with some flat terrains on the valley floor. The valleys of the Fang, the Lao and the Kok rivers from Chiang Rai to the mouth are flat lands interspersed with small hills and undulating topography. The flat bottom and depression areas are flood prone. The land uses in the flood prone areas are characterized by marginal land and some rice fields. This implies that generally flood damage is not relatively high compared to other regions where community or large farm lands are located in flood prone areas. (Sompong, 2015)

The Mueang Chiang Rai and Chiang Saen Districts are in the lower parts of the Kok River Basin. The major part of the city of Chiang Rai is enclosed by the Nam Mae Kok and Nam Mae Korn rivers. Flood prone areas in the Nam Mae Kok Basin are as following:

- Valley of Nam Mae Fang River;
- Mueang Chiang Rai district; and
- Mouth of Nam Mae Kok River (Chiang Saen District)

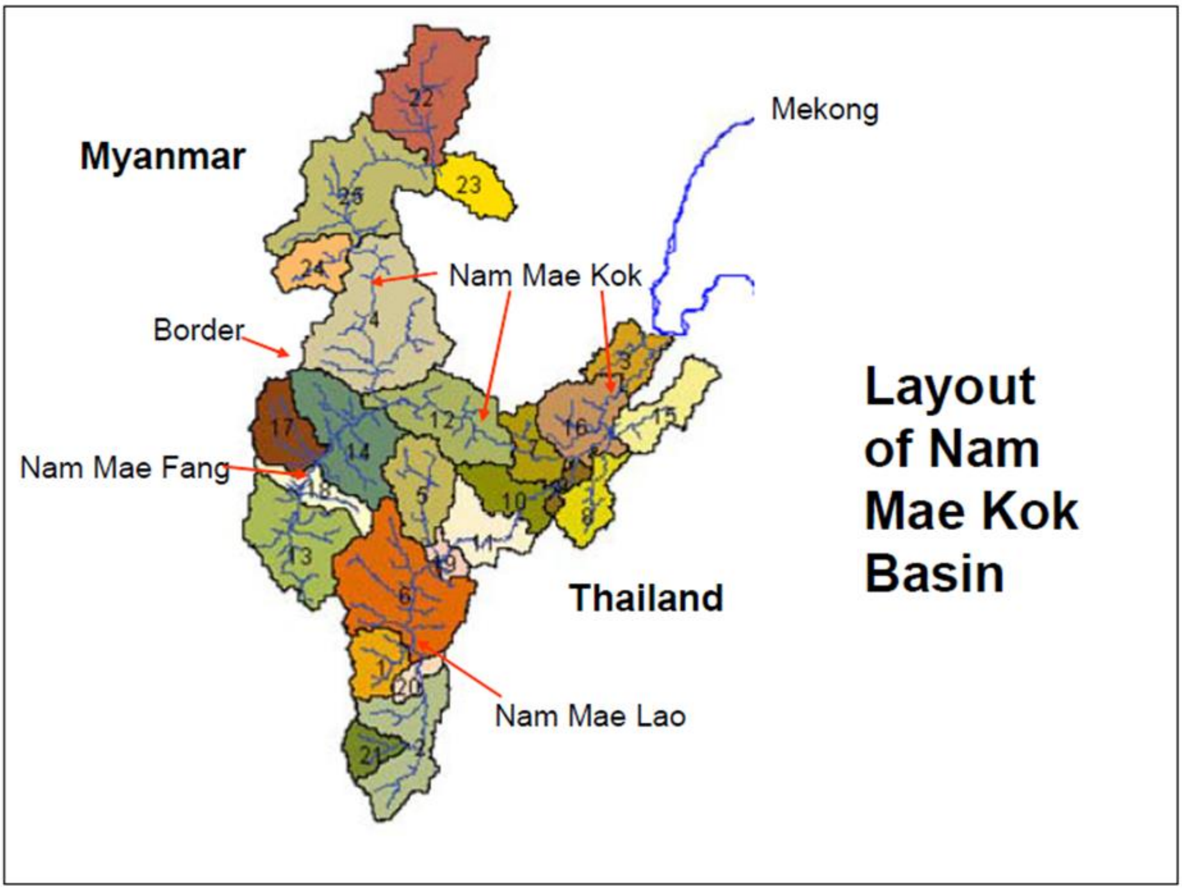

Figure 1 Layout of Nam Mae Kok Basin (Sompong, 2015)

WATER RELATED ISSUES

The climate of the Kok River Basin is dominated by tropical monsoon or tropical savanna climate. The rainy season occurs during May-October and is influenced by the Southwest monsoon from the Andaman Sea as well as typhoons and depressions from the South China Sea. Rains scatter widely over the whole area with a peak in August. (Sompong, 2015)

Winter lasts from October to February. The area is subject to the influence of the Northeast monsoon, which brings cold and dry weather from China, thus causing low temperatures over the area. The mean minimum temperature in January is 11.9 °C in Chiang Rai. The summer is between February and mid-May. Maximum mean temperature occurs in April which is 34.9 °C for Chiang Rai. (Sompong, 2015)

FLOOD SITUATION IN KOK RIVER BASIN

The flooding issue of the Nam Mae Kok is a good example of a medium size basin with both urban and rural area at flood risk. There have been a number of interventions at Chiang Rai including construction of gated structures, embankments, river realignment and a diversion channel. The sources of flooding cover s all the main types including flash flooding in the upper catchment, local runoff in the city of Chiang rai, fluvial flooding from the Kok River and the main tributaries and the backwater influence of the Mekong River (Anthony, 2017)

Flooding at the downstream reach of Nam Kok especially the last 50 km length occurs regularly by the influence of high water level and backwater from Mekong River. Backwater effect may reach about 10 km upstream of Nam Kok and Mekong junction. Flood extent of the Lower Nam Kok covers around 1 km from the river center line to both the left and right sides. The river width of Lower Nam Kok in average is about 130 m. Nevertheless the high water level and more backwater effect from Mekong River cause more the overbank flows from Nam Kok and flood depths in Nam Kok floodplains but the flood extent does not increase considerably because those floodplains are scoped as narrow band by mountains.

The floodplain locating between Nam Korn and Lower Nam Lao includes some part of Chiang Rai Municipality which faces with flood problem especially since year 2001. The total area of the floodplain is more than 50 km^2. Besides the aforementioned floodplain, the areas along the left bank of Nam Korn, also include some parts of Chiang Rai Municipality, are also facing with flood problems. Figure 2.2-1 displays flood coverage, flood ways and flood directions in the Nam Korn – Nam Lao floodplain. The main cause of flooding is the overbank flows from Nam Lao at upstream points of Chai Sombat Weir. Due to the maximum water level of Nam Lao in flooding season may reach +401.50 m.msl whilst the elevations of Chiang Rai Municipality vary from +392.00 to +396.00 m.msl, with higher elevation the abovementioned overbank flows from Nam Lao direct to Nam Korn through the so-called “Nam Lao Noi”. The water from Nam Lao is divided to two portions, the first directs to Nam Korn, due to its small capacity the overbank flows from Nam Korn occur at downstream of Nam Korn – Nam Lao Noi junction and cause flooding downstream. Another portion of water performs sheet flow along the floodplain until Nam Kok. Also the overbank flow of Nam Korn itself may occur at the upstream points of main road no.1, however the overbank flow returns back to the river just upstream of the road. The Flood model summary from task 1 of Nam Mae Kok river basin was describe the significant change in flood behavior due to development in the Chiang Rai area plus Climate Change including upstream flows and Mekong River.

The possible flood extent in the lower part of the Nam Mae Kok River Basin derived from hydraulic model calculations shows flooding near the confluences of the tributaries in Chiang Rai and along the Nam Mae Kok River between Chiang Rai and the river mouth (**Figure 2**). The flooding is more of flash flood type lasting for few days (3-5 days). (Sompong, 2015)

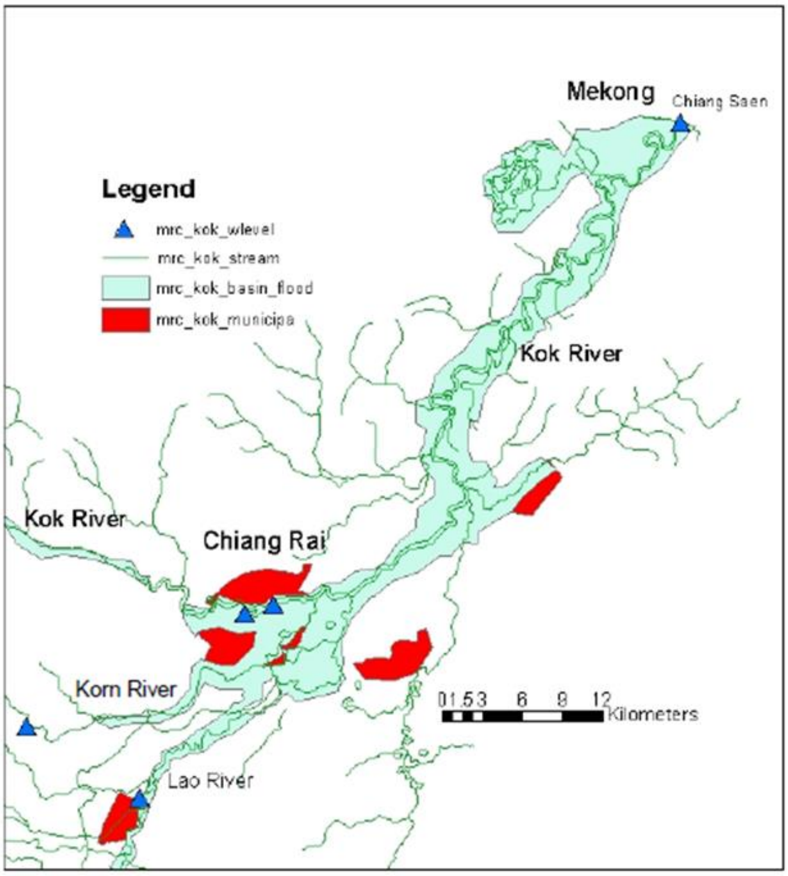

Figure 2 Flood Prone Area in Kok river Basin (Sompong, 2015)

SOCIO-ECONOMIC DEVELOPMENT ISSUES

Current socio-economic background is the main input to the 2060 development scenario, the following socio-economic data are collected for Thailand, Chiang Rai Province and Mueng Chang Rai District. Task 5a and 6a of the Initial Study (IS), agricultural sector is the main damage. Based on this reason, agricultural sector is also considered as one of the main issues. Basic Socio-Economic Indicators, Thailand, Chiang Rai Province ad Mueng Chaing Rai District are presented in **Table 1** (2014)

Table 1 Basic Socio-Economic Indicators, Thailand, Chiang Rai Province and Mueng Chaing Rai District, 2014

Indicator	Thailand	Chiang Rai Province	Mueng Chaing Rai District
Estimated Population (heads)	65,124,716	1,207,699	229,133
Population Growth Rate (% pa)[a]	0.39%	0.16%	0.48%
Rural Population (%) (non-municipal area)	55.85%	72.01%	44.56%
Population Cohort, 0-14 yrs	11,699,299	190,724	35,979
Dependency Ratio (%)[b]	38.64%	35.23%	34.42%
GDP (USD Billion)	406.52	2.86	Na[c]
Total Land (km^2)	513,115.02	11,678.37	1,577.87
Agricultural GDP (% National GDP)	10.07%	39.08%	Na
Agricultural GDP/agricultural worker (USD)[d]	5,763.7	5,742.26	Na
Agricultural GDP/ha of agricultural land (USD)	1,715.24	2,320.16	Na

Note: Data are compiled from various sources, *viz.* Department of Provincial Administration (Ministry of Interior), Ministry of Agriculture and Cooperatives, National Statistical Office (NSO), and National Economic and Social Development Board (NESDB).

[a] Calculated from the population of 2010 and 2014

[b] Dependency Ratio (aged under 15 and over 65 years combined) per 100 adults of the population (aged 15-65)

[c] GDP data are only available at the national and provincial levels (the latter is called GPP – Gross Provincial Product). Hence, GDP for Mueng Chiang Rai or other districts are not available.

[d] In 2014, the numbers of registered farmers in Thailand and Chiang Rai are 7,105,336 and 194,941, respectively.

Based on the contribution of national GDP, **Table 2** shows GDP in each economic sector. Service and manufacturing sectors are the main economic engine of Thailand; however, agriculture is always related with social issues. **Table 3** shows in case of provincial level. Agricultural which is the main issue in Task 5a and 6a can be classified as in **Table 4**.

Table 2 Contribution to National GDP, General Sectors

Year	Sector Contribution to National GDP (%)				GDP
	Agriculture	**manufacturing**	**Services**	**Total**	**(USD Billion)**
2010	10.53%	40.01%	49.46%	100.00%	340.628
2011	11.59%	38.07%	50.33%	100.00%	370.840
2012	11.51%	37.43%	51.06%	100.00%	397.600
2013	11.32%	36.98%	51.70%	100.00%	420.474
2014	10.07%	36.94%	52.98%	100.00%	406.519

Source: NESDB, 2017

Table 3 Contribution to Chiang Rai Province GDP, General Sectors

Year	Sector Contribution to National GDP (%)				GDP
	Agriculture	**manufacturing**	**Services**	**Total**	**(USD Million)**
2010	36.14%	12.49%	51.38%	100.00%	2,194.776
2011	34.79%	12.63%	52.58%	100.00%	2,418.233
2012	40.02%	9.50%	50.48%	100.00%	2,850.112
2013	39.31%	10.49%	50.19%	100.00%	3,050.833
2014	39.08%	10.01%	50.91%	100.00%	2,864.166

Note: GDP data are only available at the national and provincial levels (the latter is called GPP – Gross Provincial Product). Hence, GDP for Muang Chiang Rai or other districts are not available.

Table 4 Value of Agriculture, Chaing Rai Province

Year	Value of Agricultural Sub-Sectors (USD Million)		
	Agriculture, hunting, forestry	**Fishing**	**Total (GPP)**
National level			
2010	9.59%	0.94%	10.53%
2011	10.62%	0.97%	11.59%
2012	10.59%	0.91%	11.51%
2013	10.53%	0.80%	11.32%
2014	9.24%	0.83%	10.07%
Chaing Rai Province			
2010	35.04%	1.10%	36.14%
2011	33.75%	1.03%	34.79%
2012	39.12%	0.89%	40.02%
2013	38.38%	0.93%	39.31%
2014	38.16%	0.93%	39.08%

Production of Agricultural Crops, Chiang Rai Province and Mueng Chiang Rai District is shown in **Table 5**.

Table 5 Cultivation and Production, Chiang Rai Province in 2014.

Crop	Harvested area (ha)		Production (Tons)	Farm price (USD/t)[a]	Farm Value	
	Area (ha.)	(%)			USD (m)	USD/ha
Major Rice	192,903	98.44%	715,448	281.10	201.11	1,042.55
Second Rice	80,884	98.45%	350,523	226.69	79.46	982.41
Maize	81,673	98.54%	349,447	219.52	76.71	939.24
Cassava	9,846	96.91%	201,708	65.58	13.23	1,343.52
Oil Palm	923	48.46%	7,427	131.47	0.98	1,057.62
Soybean	3,473	100.00%	4,922	483.68	2.38	685.52
Garlic	402	98.13%	2,200	2,375.31	5.23	12,996.61
Shallot	134.88	97.34%	1,195	448.28	0.54	3,971.60
Onion	179	99.38%	3,752	282.64	1.06	5,912.40
Potato	804	87.42%	17,543	377.16	6.62	8,232.67
Pineapple	1,652	100.00%	31,237	220.14	6.88	4,163.26
Longan	20,819	99.26%	79,150	781.10	61.82	2,969.65
Rambutan	827	77.40%	8,467	564.66	4.78	5,780.78
Mango	44.48	53.46%	96	621.31	0.06	1,340.95
Lichee	3,680	94.69%	7,084	360.22	2.55	693.40
Tangerine	495.04	81.49%	5,832	1,034.17	6.03	12,183.48
Longkong	140.96	71.63%	285	408.56	0.12	826.05
Coffee	5,414.88	71.82%	3,451	1,999.38	6.90	1,274.24
Para rubber	37,156.8	67.29%	36,803	1,660.41	61.11	1,644.60
Totals	**441,451**		**1,826,570**		**537.55**	

Source: Ministry of Agriculture and Cooperatives

[a] Farm price is price that farmers sold their produces at the farm; and farm value is farm price multiplied by production.

POPULATION ISSUE

Number of populations, percentage change and population density in each district are shown in **Table 6**.

Table 6 Population from Registration Record, Percentage Change and Density by District, 2010 - 2014

District	Population					Growth	Population density (per km^2)
	2010	2011	2012	2013	2014		
Mueang Chiang Rai	**223,725**	**224,677**	**226,107**	**228,049**	**229,133**	**0.48%**	**188.42**
Wiang Chai	44,036	44,128	44,314	44,449	44,668	0.28%	172.62
Chiang Khong	62,328	62,217	62,410	62,605	62,691	0.12%	74.91
Thoeng	84,018	83,923	84,102	84,196	84,249	0.05%	102.62
Phan	124,364	123,676	123,425	123,141	122,646	-0.28%	119.89
Pa Daet	26,362	26,281	26,267	26,290	26,340	-0.02%	79.03
Mae Chan	99,273	99,232	99,131	99,181	99,185	-0.02%	125.40
Chiang Saen	**50,323**	**50,147**	**50,116**	**50,210**	**50,344**	**0.01%**	**90.87**
Mae Sai	85,266	85,245	84,923	85,542	86,185	0.21%	302.40
Mai Suai	79,938	80,116	79,918	80,222	80,439	0.12%	56.31
Wiang Pa Pao	67,092	67,101	67,080	67,236	67,182	0.03%	55.20
Phaya Mengrai	41,952	41,947	42,039	42,105	42,167	0.10%	68.01
Wiang Kaen	31,254	31,440	31,799	32,215	32,858	1.00%	62.47
Khun Tan	32,341	32,189	32,170	32,085	31,955	-0.24%	136.56
Mae Fa Luang	69,567	69,731	69,602	69,828	70,207	0.18%	109.46
Mae Lao	30,631	30,688	30,811	30,825	30,853	0.14%	75.99
Wiang Chiang Rung	26,740	27,012	27,254	27,477	27,601	0.63%	104.83
Doi Luang	19,008	18,906	18,955	19,004	18,996	-0.01%	85.18
Total	1,198,218	1,198,656	1,200,423	1,204,660	1,207,699	0.16%	103.41

Source: Department of Provincial Administration, Ministry of Interior, 2017

Because of the increasing of population, city may expand. The city has a possibility to expand to the east to Wiang Chai District and grow up in the north to Mae Chan District. In the far future, resident area will expand to flood plain by

Real estates, condominiums and high building. Condominium will occur along Mae Kok River, while real estate will occur in expanded area.

Mae Sai may have high building for trading company, hotel and department store. High building may occur along the main road and ring road. Slum may not occur in Nam Mae Kok Basin. For green-blue concept, houses on stilts should be occur in the rural area and agricultural area along Nam Mae Kok River especially in Mae Chan District and Chiang Saen District.

From the development plan, the development of urban zones is along the road, especially on the junctions/intersection. The detail for cluster development is still under study.

There are seven towns in Lower Mae Kok Basin and Chiang Kong that have a plan to develop and expand.

- Cha Chawa community, locate near Chiang Saen and conservation zone for tourism, so it is possible to develop as green city.
- Wiang Chai community locate near Chiang Rai city. Chiang Rai city may expand to this area.
- Ban Lao community locate on the right of Mae Kok River near Chiang Rai city
- San Sai community in locate on Highway no.1, on the way to Mae Sai
- Mae Sai – Trading City
- Chiang Saen – Port and Historical Tourism
- Chiang Kong – Port and Logistic city

LAND USE ISSUE

Chiang Rai has an area of 11,575.74 sq.km or 1,167,800 hectares. Approximately 42 % of total area is forest 5 % is resident and industrial area while 48 % is agricultural area referring to 2014-2017 Chiang Rai Development Plan.

From Department of land development (2011), land use in Chaing Rai is show in **Table 7**. This table shown that most of area in Chiang Rai is still green area and almost of half of this green area is agricultural area. Base of this situation, the goal for development of Chiang Rai and Nam Mae Kok River Basin will be (1) an organic and chemical-free farming production base, linked to the value – added agro processing industry and (2) nature and culture tourism, health care and educational business center in sub-regional area. The border city will play important roles in logistics and cross-border trade which linked with the country's central production base.

Table 7 Land use situation of Chiang Rai in 2011

Land use	Area (sq.km)	Percentage
Agriculture	5,579.28	48.20
Forest	4,881.90	42.17
Miscellaneous	328.46	2.84
Urban	494.57	4.27
Water Resources	164.63	1.42
Government and Institution	47.15	0.41
Industries	11.44	0.10
Aquaculture	31.11	0.27
Facilities	9.84	0.09
Recreation	27.36	0.24
Total	11,575.74	100.00

According to the Chiang Rai development plan from Department of Public works and Town & Country Planning announced on 2013 in **Figure 3**. Almost area in Nam Mae Kok Basin is agriculture and forest (green area) and agriculture reform area (green area with red line). There are only two zones for industry: Chiang Kong District and Teng District.

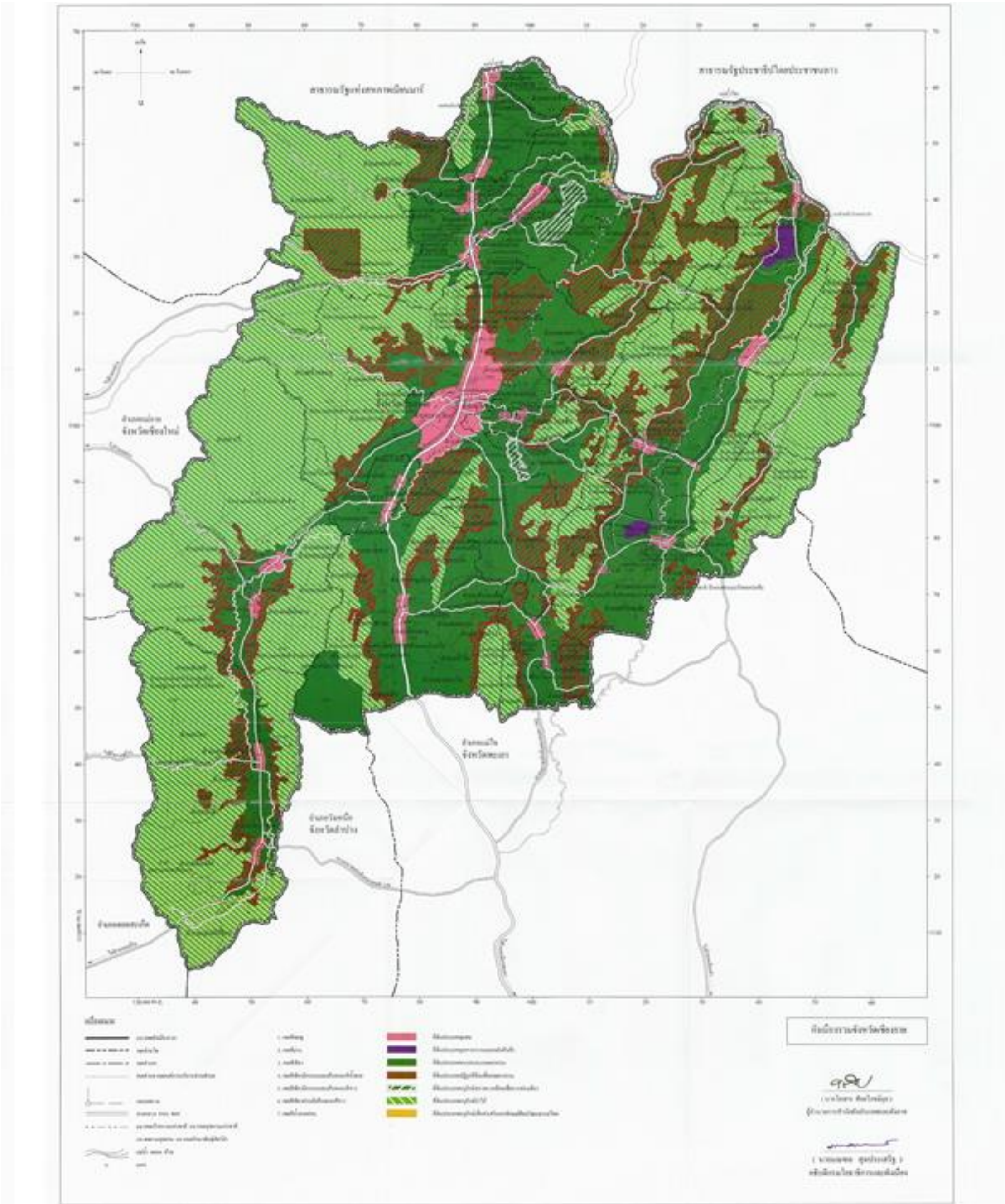

Figure 3 Land use planning in Chiang Rai province

Map Legend:

Community Area

Industrial and Cargo Area

Rural and Agricultural Area

Reformed Agricultural Area

Environmental Preservation Area for Tourism

Forest Conservation Area

Protected Area to Promote Thai Arts and Culture

Opportunity for linking with countries in the region

From 2014-2017 Chiang Rai Development Plan. The SWOT analysis of Chiang Rai province is show in **Figure 4**.

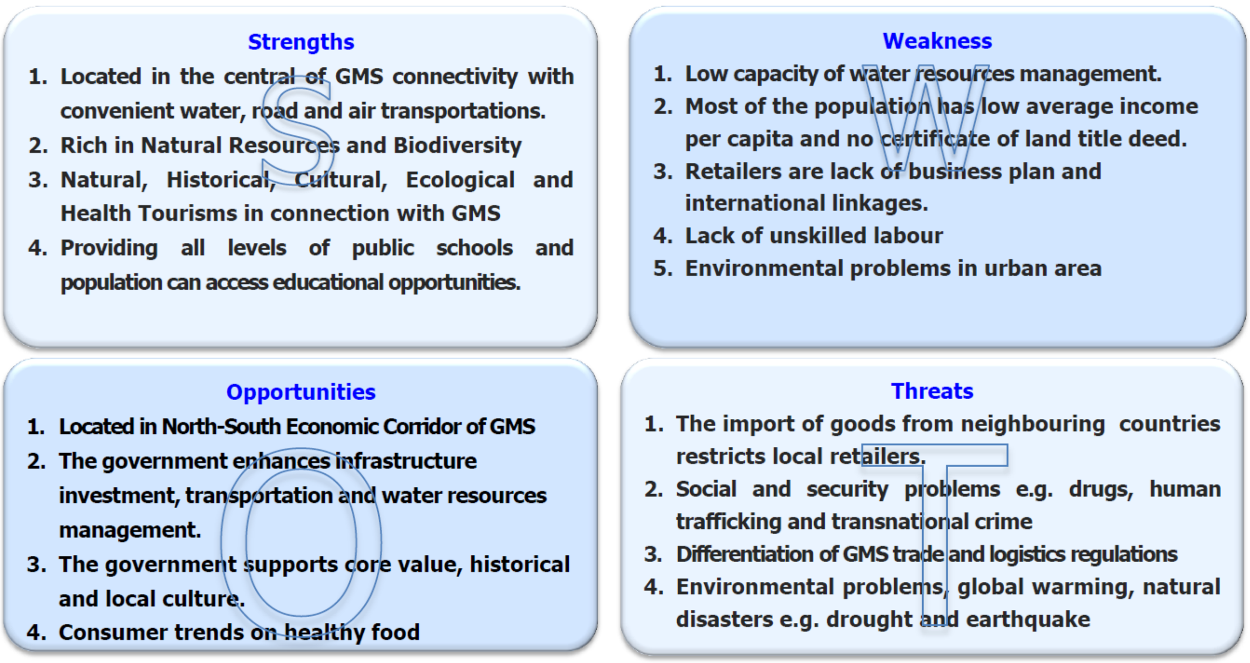

Figure 4 SWOT analysis of Chiang Rai

INDUSTRIES DEVELOPMENT

At the present, major industries in Chiang rai are agro-related industries, food industries, non-metallic industries such as ceramic, textile and jewellery. The industrial area is concentrate around Chiang Rai city, Pan District, Mae Chan District and Mae Sai District. Some area in Phraya Meng Rai District and Teng District. All of them is locate along the road. Current industrial area is show in **Figure 5**.

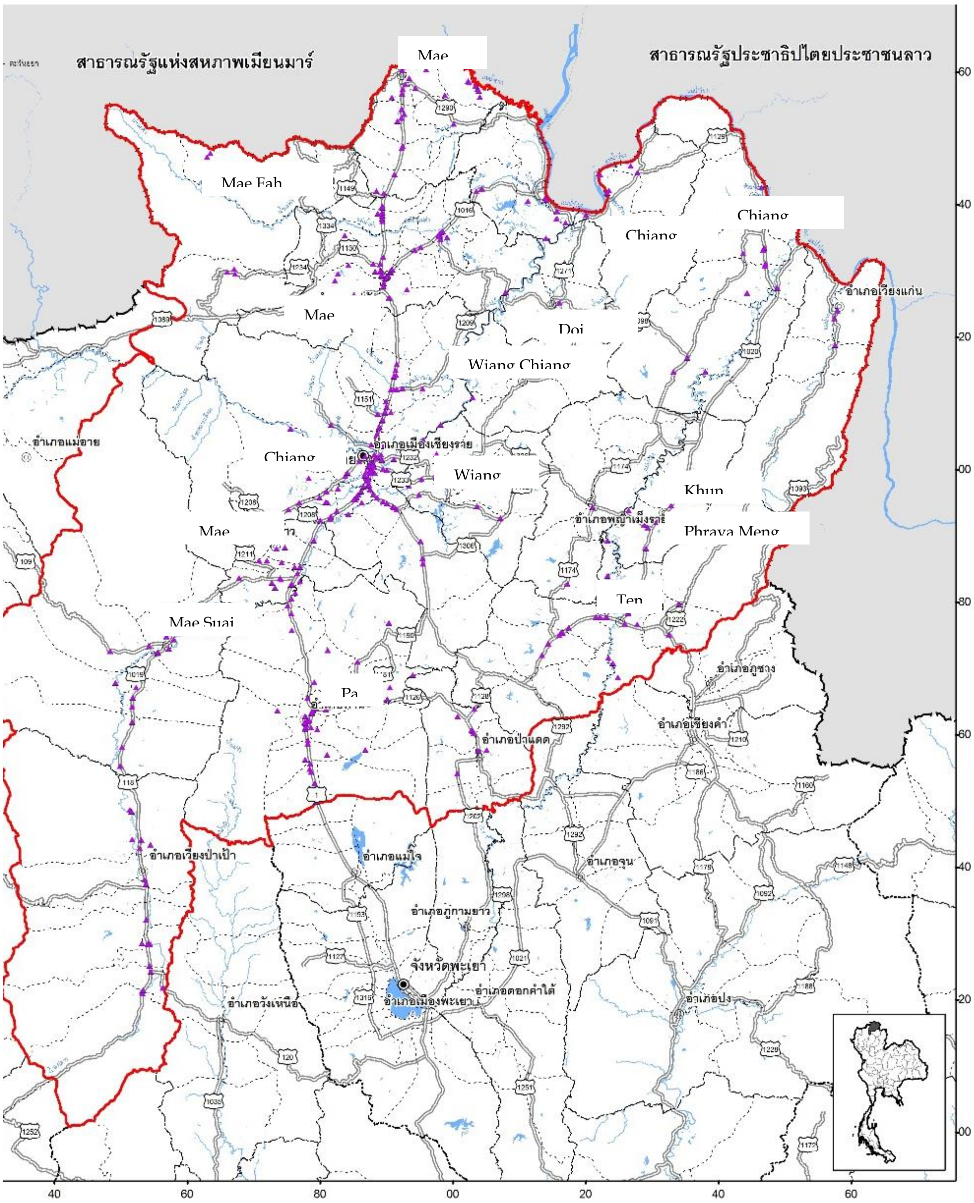

Figure 5 Current Industrial Area (Department of Industrial Work, 2016)

The potential area for industries in Chiang Rai present by Department of Industrial Works (2016) show in **Figure 6**. The potential industrial area is located along the road (Purple and yellow area). The high potential area are in Mae Sai District and Teng Distriact large (Purple area)

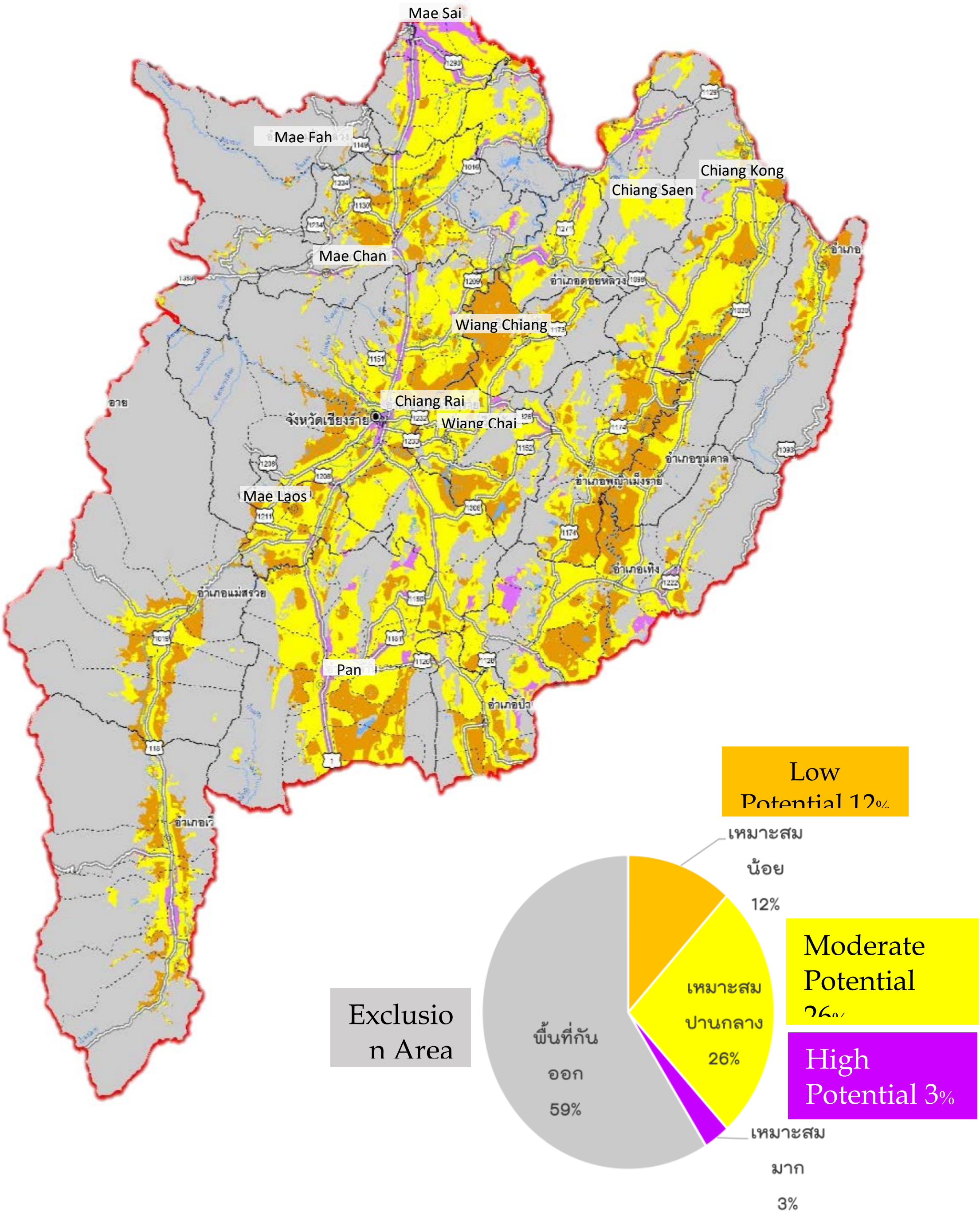

Figure 6 Potential Area for Industries

TRANSPORTATION ISSUE

Existing railways and planned railways

Previously, the state railway of Thailand has no route to Chiang Rai, the nearest station is situated at Den Chai district in Phrae province. Recently, due to AEC and GMS Economy corridor, the State Railway of Thailand has planned to construct the routes from Den Chai to Chiang Saen Port II (Port City) and Chiang Khong Thai-Laos Friendship Bridge (Logistic City). This Den Chai – Chiang Rai route has started from Den Chai and heads to Phayao station and continues to Chiang Rai city, Thung Ko, Wiang Chiang Rung respectively, and it has an interchange at Pa Sang station prior to separate railway into 2 routes, north direction heads to Chiang Saen Port II (Port City) and another in east direction heads to Chiang Khong Thai-Laos Friendship Bridge (Logistic City).

On March 17, 2017 the ministry of transportation has said that the construction of railways project from Denchai to Chiang Rai has to be postponed to year 2021 due to the EIA processing; part of railway routes has passed through class 1A of wet land forest and mountain.

The ministry of transportation has confirmed that this project has to be constructed once the EIA has approved. The drawing of the project has been completed and can be minor adapted and revised to follow the EIA recommendation (323 km. that passed through 59 sub districts, 17 districts, 3 provinces with 26 stations and 3 tunnels (1st tunnel 6.4 km. long @ Song district in Phrae Province, 2nd tunnel 2.8 km. long @ Muang district in Payao Province and 3rd tunnel 3.6 km. long @ Doi Luang district in Chiang Rai Province).

The budget about 77 billion THB (2,300 million USD) of this railway project has been set (73 billion THB for engineering construction and other 4 billion THB for land and properties compensation) and the duration of railway construction will be completed within 48 months (or 4 years) according to the ministry of transportation Thailand.

The ministry of transportation has pointed that this railway from Denchai to Chiang Rai is very important for Thailand, because it can be link to Laos PDR in Chiang Khong at Thai- Laos Friendship Bridge to facilitate transportation, especially border goods and possible to transport the goods further to China via China-Laos railway project at Na Toey in Luang Nam Tha Laos PDR in the coming years.

Road and railway planning issues

The 2 Ring Roads has started from the city of Chiang Rai head to Chiang Saen in the north direction – the Ring Road no.CR 1063, its alignment has almost along with both sides of Kok River and the rural road department planned to build 3 number of bridges crossing Kok river (1st Bridge near Wat Phra That Wang Sang in Chiang Saen district (completed on July 2015), 2nd and 3rd Bridge near Wat Pha Ban Sai Thong in Doi Luang district (under construction) and another Ring Road alignment heads along Highway no. 1016 (upper yellow line from the left hand on the map showed below **Figure 7**).

Figure 7 Map of railway ang ring road

The map above has also indicated the alignment of planned railway (the orange line in y-shape) that link between Den Chai district in Phrae province. The railway pass through the city of Chiang Rai and heads to the city port in Chiang Saen and terminate at the logistic city that close to Thai-Laos Friendship Bridge in Chiang Khong.

Flood concerning due to the construction of bridges crossing Kok River on Ring Road CR 1063. The bureau of bridge construction under the rural road department has been design all together 3 bridges crossing Kok River for Ring Road no.CR 1063- one bridge near Chiang Saen Port has completed on July 2015 and the other two bridges in Doi Luang district are under construction.

The two pictures below showed the location and side view of bridge crossing Kok River on Ring Road CR 1063 near Wat Phra That Wang Sang, Chiang Saen district.

Figure 8 Location of bridge near Wat Phra That Wang Sang

Figure 9 showed the side view of bridge on the Ring Road no. CR 1063 that crossing Mae Kok river near Wat Phra That Wang Sang that located about 5 km. from Chiang Saen Port II.

The hand sketching is the detail of bridge on the Ring Road no.CR 1063 that crossing Kok river near Wat Phra That Wang Sang. The width of Kok River in this section is about 140 metres, the bureau of bridge construction has constructed its piers into 3 channels one is 65 metres width in mid span and another 2 channels are 37.5 metres for each side of river bank. The rural road department has confirmed that this bridge can be safe to carries the heavy transport trucks and the width of 65 metres mid span of the bridge will be optimised for the flow rate of Kok River in flood period.

Figure 9 Bridge near Wat Phra That Wang Sang

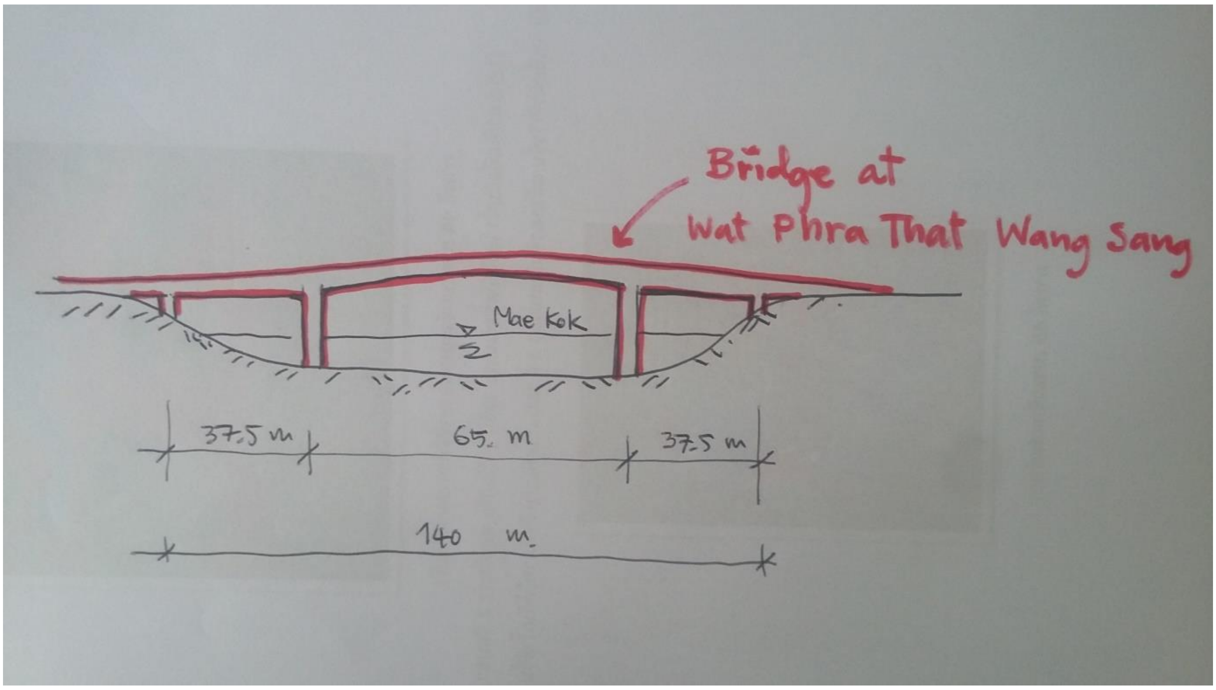

Figure 10 Bridge near Wat Phra That Wang Sang (sketching)

SPECIAL ECONOMIC ZONES

The current development of Chiang Rai's SEZ can be summarized as follows.

Establishment of One Stop Service (OSS - a centre integrating services from government agencies and investment-related agencies) to facilitate trade and investment in the SEZs.

Four OSS centres have started operation in the following areas:

- Dhamrongdhamma Centre, Muang Chiang Rai
- District Office, Mae Sai
- District Office, Chiang Saen
- District Office, Chiang Khong

Land preparation is under derogation of the land owner right in the following locations:

- Chiang Khong District: Ban Ton Ngiew, Sub-district Sathan covers the area of 88.528ha.
- Mae Sai District: State property land 139.248ha.
- Chian Saen District: Land reformed area at Ban Saeo 104.208ha

Cooperation agreements between countries

Thailand- Myanmar: Legal agreements were signed between Thailand and Myanmar on 24 June 2016 on

(1) Agreement on Border Crossing between the two countries ,

(2) MoU on Labour Cooperation, and

(3) Agreement on Employment of Workers.

Thailand-Lao PDR: The agreement on border crossing between Thailand and Lao PDR are in the process.

Infrastructure construction

- Department of Rural Roads is responsible for the construction of Provincial Highway 1020 (43.71km) from 1020 junction to Ban King Kaew, Thoeng District (expected to complete on 13 January 2018).
- Intermodal Facilities Centre, Chiang Khong, is currently under the process of land reclamation (the construction is scheduled to complete in 2019).

- Department of Highway is constructing the 3rd phase of Provincial Highway 1290 from Chiang Saen to Chiang Khong (21km.). The 1st and 2nd phases are completed, the 3rd phase is under construction and expected to complete on 18 June 2018 (see Fgure 6.3 below).

<u>Customs/border crossing system</u> (CIQ. – Customs Inspection and Quarantine)

Mae Sai and Chiang Saen Customs are under construction:

(1) Chiang San: New office building of Mae Sai Customs is under construction at Ban Saew district.

(2) Mae Sai: Facilities building, land improvement for car park, service yard, and loading cargo.

CHIANG RAI PROPOSED AS LOGISTIC HUB FOR MEKONG REGION

Three districts of Chiang Rai are perfectly positioned to serve as the logistics hub for the Greater Mekong Sub-region, according to the Ministry of Industry, and has promoted into the Special Economic Zone in order to support the integration of the ASEAN Economic Community (AEC)

Industrial Estate Authority of Thailand (IEAT) is increasing the investment value to the Chiang Khong industrial estate in Chiang Rai and aims to improve infrastructure that will connect ASEAN to southern China, according to ministry of industry.

Chiang Rai SEZ development includes four strategies with the first being promoting industrial development and sustainable manufacturing integration. That is to be followed by strengthening the efficiency and competitiveness of the industrial manufacturing, followed by promoting eco-friendly industries, and finally promoting broader investments to support the border areas and the AEC.

Mae Sai has two custom checkpoints, previous one is situated on road no 1 and later in 2007 the second (new) has been built on the road no 123 between Thailand-Myanmar border. The second custom checkpoint has been developed to serve the expansion of AEC economy.

GMS Trading city that link between Thailand, Myanmar and China, the border trade and tourism has to set in this location.

Chiang Saen has 2 ports-- one for goods transport and second for tourism industry. At first the marine department has used Port 1 for goods transport but later on they has hand over to community administration for tourism industry purpose.

Recently, the marine department has issued Chiang Saen Port 2 as City Port. Chiang Saen will set as Port city that link between 4 countries i.e. Chiang Rai, Laos, Myanmar and China. The historical tourism and logistic city & river tourism will be included in these port areas.

Chiang Khong is the location of Thai-Laos Friendship Bridge that will suitable to set as the logistic city & transportation services that link between 3 countries i.e. Thailand, Laos and China. The transition city for tourist has to be concluded in the Friendship Bridge area.

The river tourism from Ho Chi Minh to China can be done along Mekong River but water transport might not suitable for huge goods transportation in very long route of Mekong river which flow from very high mean sea level and discharge down to the sea, additionally, all the big boats will take time due to the transferring via navigation lock for 8-10 hydropower dams crossing Mekong River that will be constructed in the future.

The improvement of the navigability of the Mekong River (about 231 kilometres) for 150 DWT ship in Rainy season and 50 DWT ship in drought season has been done since 2002.

Later, the improve the navigability of the Mekong river from border of China and Myanmar to Luang Phrabang, Laos (about 631 kilometres) for 500 DWT carrier ship in Rainy season has to be planned on 2015-2020 and the planning will continue improve from Simao, China to the border of China and Myanmar (about 259 kilometres) on 2020-2025.

The travel time from Simao, the farthest port in China to Chiang Saen is about 8 days (621 kilometres) while travel time from border of China and Myanmar to

Chian Saen is about 4 days (361 kilometres). This approximate time is base of average travel time of ship of 80 kilo metres per day. Anyway, it is depending on the operation of navigation lock for number of hydropower dams crossing Mekong River in the next 10 years and capacity of port itself.

3.3 STATUS OF NAM MAE KOK (NMK) SUB-BASIN IN THE FUTURE

SCENARIO BASED APPROACH

The scenario thinking is needed to predict the future because NMK sub-basin have a present situation and present policies, but NMK sub-basin have an uncertain future including

- (un)successful land-use and water-management policies
- (un)successful international co-operation on water-use
- climate for high economic development or low
- strong climate change or not

Based on these uncertainties, development may go different ways and thus also impact on river flow, floods and droughts.

NMK sub-basin need to answer the question how we need to adapt our policies to enhance socio-economic development, to be safe and make that work for a long period. Based on these issues; socio-economic development including land use are as important as climate change.

NMK sub-basin should development including sustainable socio-economic development with environmental protection and flood protection for people, planet and profit as shown in **Figure 11**.

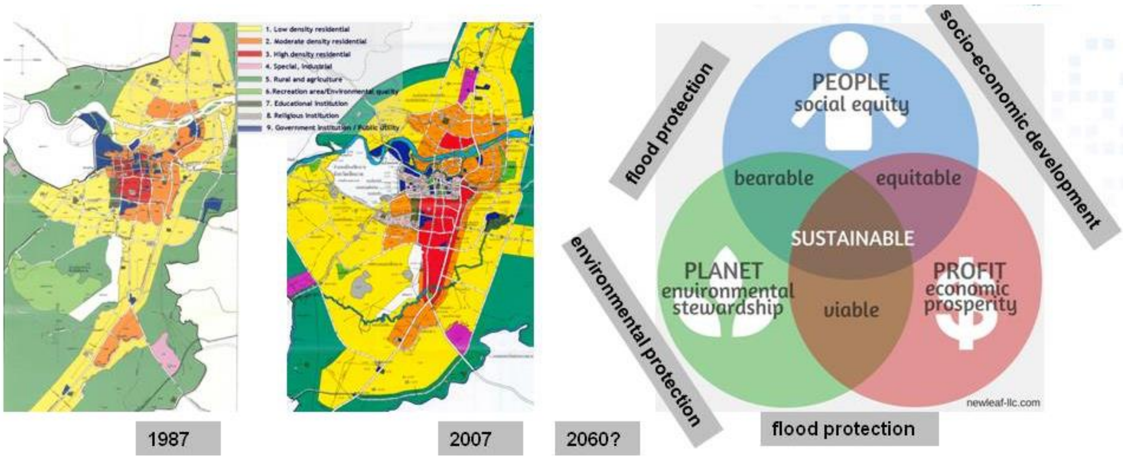

Figure 11 Prosperity, safety and sustainability (MRC, 2017)

SWOT analysis of the country and the NMK sub-basin is discussed from trends to scenario, business as usual to policy adjustments to reduce negative impacts and enhance economic development as shown in **Figure 12**. This is one of important activities during workshop of the Preferred 2060 Floodplain Development (FPD).

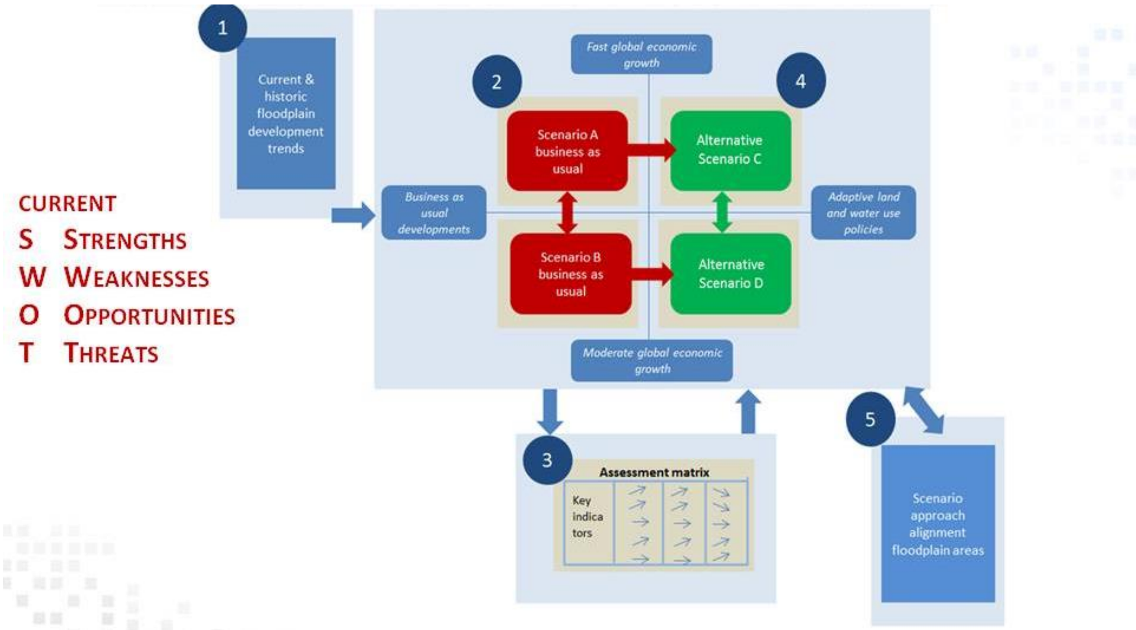

Figure 12 SWOT analysis of the country and the floodplain (MRC, 2017)

Impact factors in future flood risk that should be in the scenarios is shown in **Figure 13**.

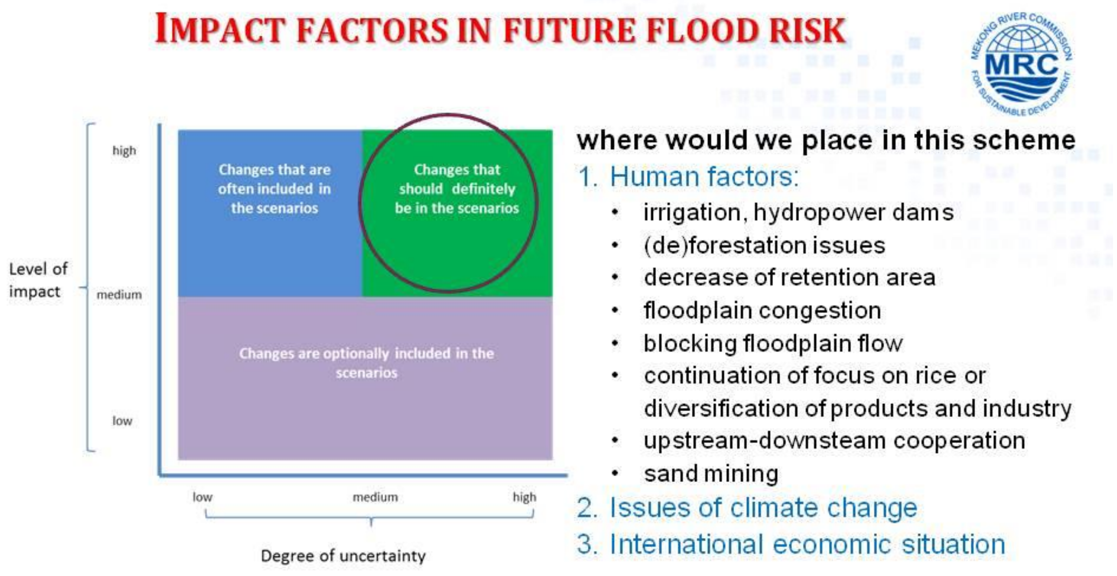

Figure 13 Impact factors in future flood risk (MRC, 2017)

DRIVER FOR DEVELOPMENT FROM NATIONAL POLICY

Thailand has continuously been improving its economic model, starting from "Thailand1.0," which focused on the agricultural sector, to light industries with "Thailand 2.0," where the country utilized cheap labor cost with a focus on domestic productions, through to "Thailand 3.0," which is focused on more complex industries to attract foreign investments making Thailand a production hub for exports. However, under Thailand 3.0, the country has faced middle-income trap, growing disparities, and imbalanced development, major concerns which prompted the government to transform Thailand's economic structure to "Thailand 4.0."

Under prime minster Prayut Chan-o-cha, Thailand is focusing on becoming a value-based and innovation-driven economy by moving from producing commodities to innovative products; emphasizing on promoting technology, creativity, and innovation in focused industries; and from a production-based to a service-based economy. Major investments in infrastructure are underway including railway and airport upgrades, highspeed rail, roadways and the Eastern

Economic Corridor (EEC) as part of the government's efforts to make Thailand one of the most preferred investment destinations in Asia. One of the main targets of Thailand 4.0 is to overcome middle-income trap. This means GDP per capita of Thai citizen must increase from 5600 USD per capita in present to 15,000 USD per capita in the future. Under scenario-based approach, two scenarios are presented for business as usual (BAU) case and Thailand 4.0 case as shown in **Figure 14**. This information will be used in flood damage calculation in next task.

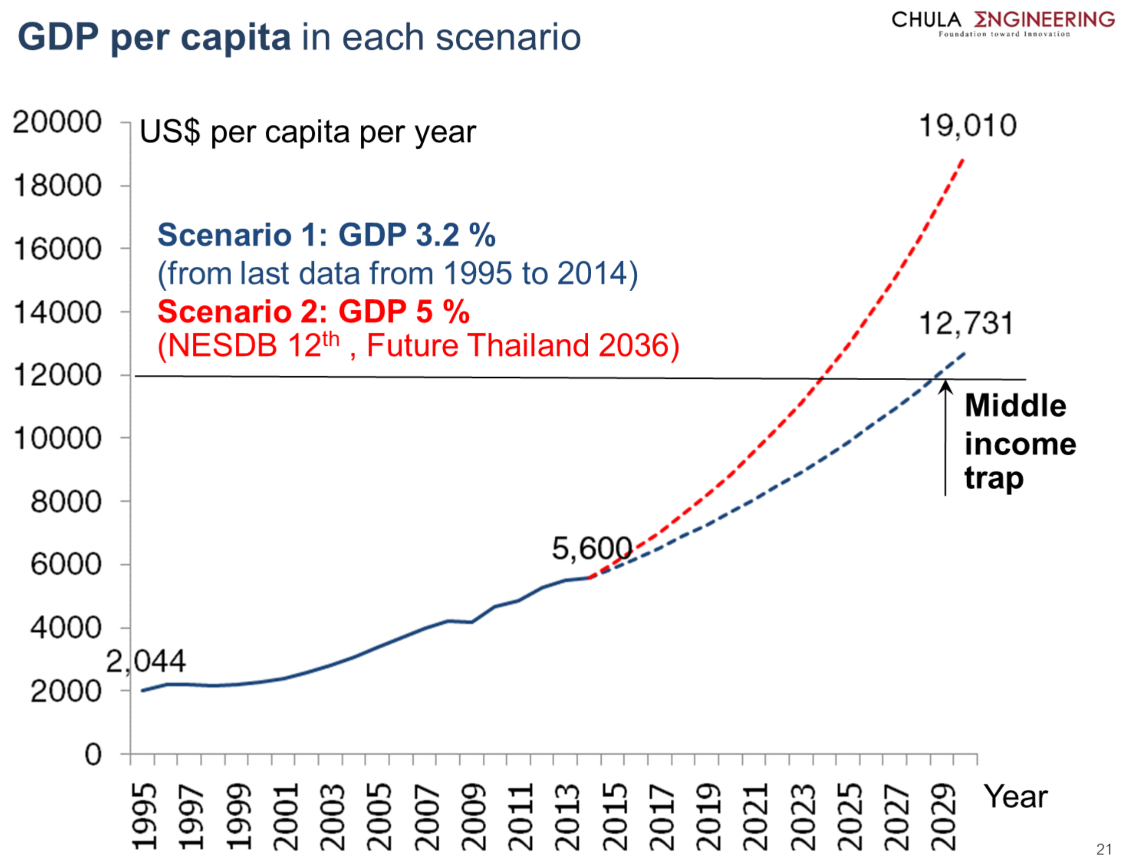

Figure 14 Middle income trap issue in Thailand

WORKSHOP OF THE PREFERRED 2060 FLOODPLAIN DEVELOPMENT (FPD)

According to Inception Workshop under Stage 2 Initial Studies; Task 4 - Possible Future Flood Behavior under Climate Change (CC), Future Upstream Developments (USDs) and the Preferred 2060 Floodplain Development (FPD) option for the Nam Mae Kok floodplain and Flood Focal Area (FFA) for Thailand held in VIE Hotel Bangkok in Bangkok, Thailand on 07 - 08 September 2017, Thai national experts in each sector discussed and confirmed scenarios of land use and water management. Three scenarios with land use and water management are considered under matrix of high/ low economic growth and successful/unsuccessful planning as shows in **Figure 15**.

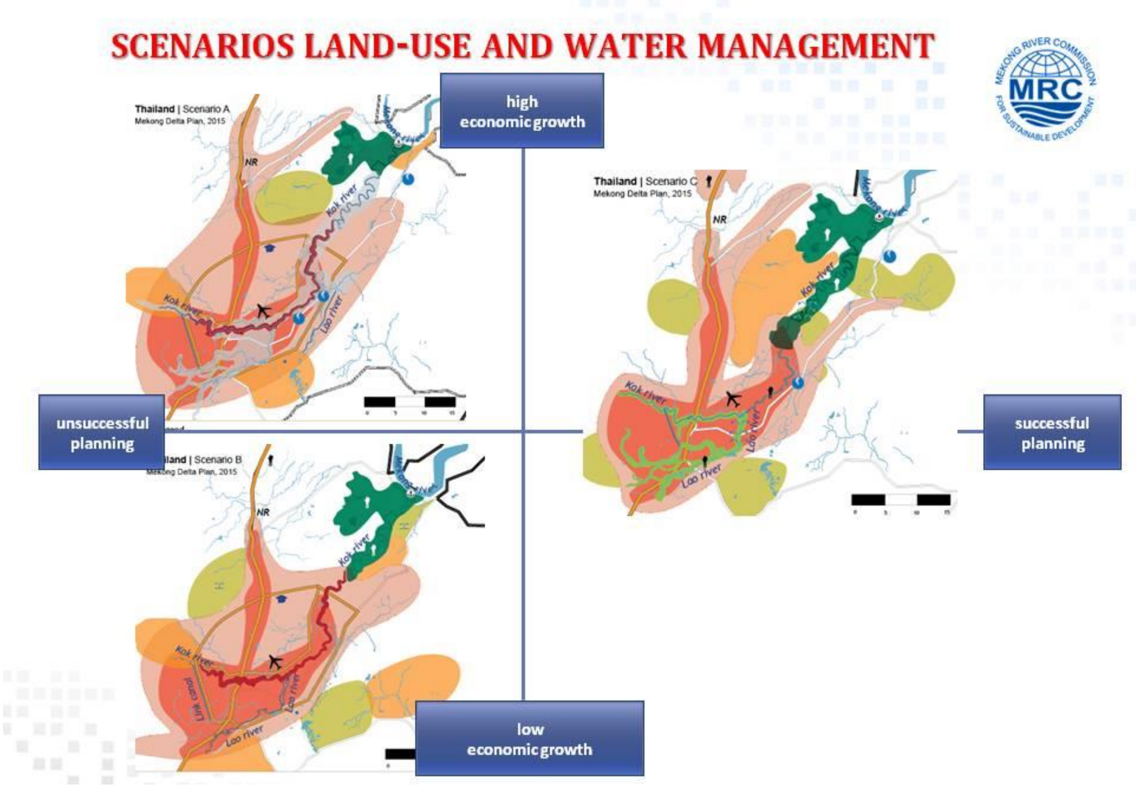

Figure 15 Three scenarios of land-use and water management (MRC, 2017)

The details of each scenario are shown in **Figure 16** and **Figure 17**.

Based on discussion in this workshop, Thai national experts confirmed scenario C as Preferred 2060 Floodplain Development (FPD). This was demonstrated by extrapolating developments taking place, a favorable economic scenario and assuming good governance and land-use and water management. It resulted in an updated picture (compared to 2015) of the high value eco-farming floodplain scenario.

All comments and recommendations from national experts is prepared for the adjustment of the model schematization for future flood behavior and calculations of the potential future flood damages.

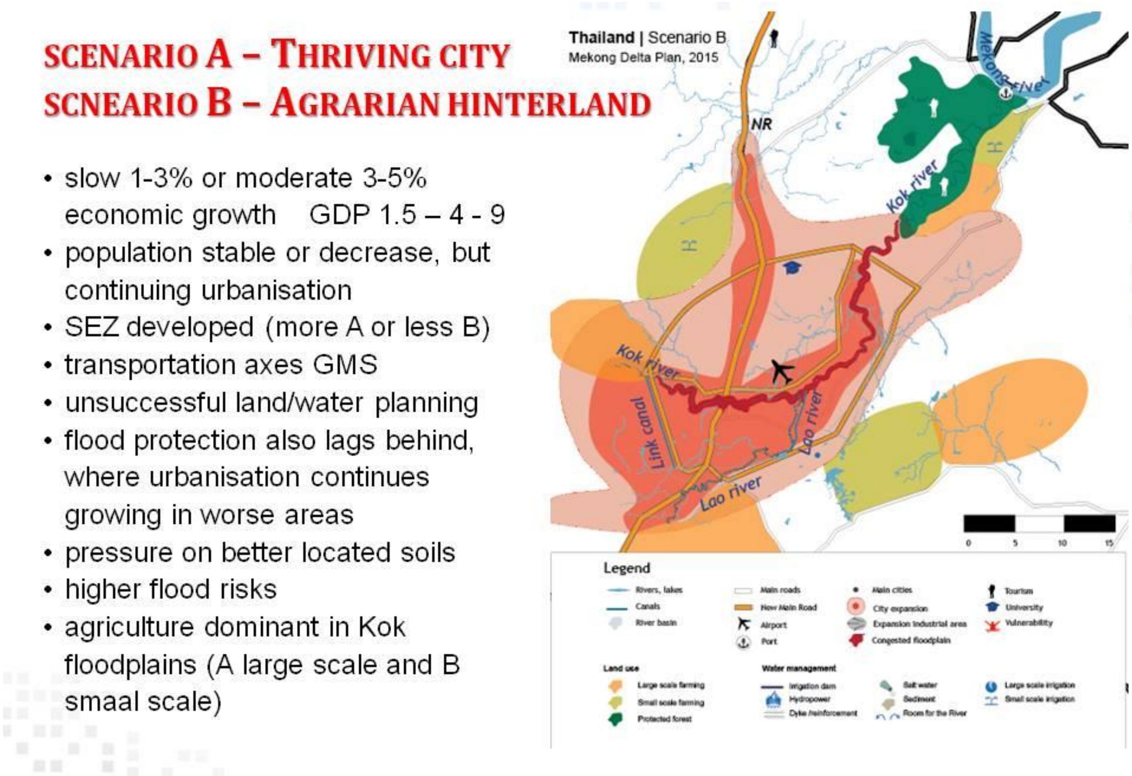

Figure 16 Scenario A and B (MRC, 2017)

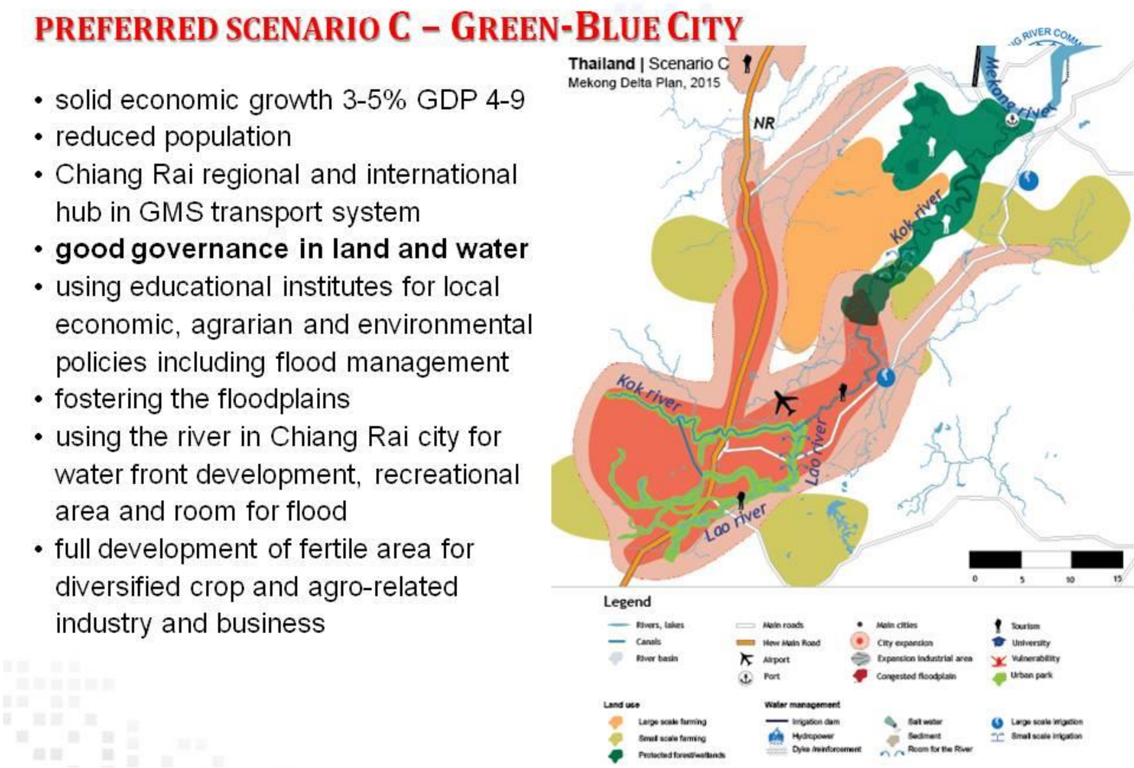

Figure 17 Preferred scenario C: Green-Blue city Agri-business to increase productivity (MRC, 2017)

3.4 DEVELOPMENT OF SCENARIOS

Based on conceptual and result from Task 3 report (MRC, 2016) and national sector report, it was identified for land use, infrastructure, agricultural and projection future development in NMK. Therefore, Floodplain scenarios were designed based on suggestion from NTWG – TNMC as describe below:

- Upstream development (USD) and floodplain development (FPD)
- Climate change
- New proposed water infrastructure

SCENARIO OF UPSTREAM DEVELOPMENT AND FLOODPLAIN DEVELOPMENT

Description of scenario under Upstream development and floodplain development is as follow:

(1) BDS0-Baseline 2014:

Scenarios on existing flood behavior and development in 2014 (Baseline condition). BDS0 refer to situation in year 2014 that have completed flood protection projected in Chiang Rai city composed of (1) Nam Korn – Nam Mae Kok Diversion canal (2) Rehabilitation of existing weirs on Nam Korn (3) Nam Korn and Nam Lao embankment improvement. Land use for BDS-BL2014 will base on current situation year 2014 and current existing structure and floodplain condition (flood cell in ISIS).

(2) BDS1-2020:

Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 25% flood storage over the NMK and definite development in 2020. BDS1 has been designed and expectation in definite future will change on Land use in upstream basin and urban expansion of Chiang Rai city. Therefore, the boundaries condition and flow inside study area will update base on results from SWAT model and flow from the Upper Mekong Basin also expected change based on Development in year 2020 using SWAT-IQQM regional model. Moreover, the affect by loss of flood storage through the urban expansion by loss of 25% of flood storage over the floodplains and expected structure in year 2020 will be revised in ISIS model

(3) BDS2- 2040:

Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 50% flood storage over the NMK and definite development in 2040. BDS2 has been designed and expectation in definite future will change on Land use in upstream basin and urban expansion of Chiang Rai city. Therefore, the boundaries condition and flow inside study area will change and update base on results from SWAT model. The Upper Mekong Basin also expected change based on Development in year 2040 using SWAT-IQQM regional model. Moreover, the effect by loss of flood storage through the urban expansion by loss of 50% of flood storage over the floodplains and expected structure in year 2040 will be revised in ISIS model.

(4) BDS3- 2060:

Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 75% flood storage over the NMK and definite development in 2060. BDS3 has been designed and expectation in definite future will change on Land use in upstream basin and urban expansion of Chiang Rai city. Therefore, the boundaries condition and flow inside study area will change and update base on results from SWAT model. The Upper Mekong Basin also expected change based on Development in year 2060 using SWAT-IQQM regional model. Moreover, the affect by loss of flood storage through the urban expansion by loss of 75% of flood storage over the floodplains and expected structure in year 2060 will be revised in ISIS model.

The historical climates data from year 1985 -2014 was applied, and no climates change consider during simulation for analysis future upstream developments (USDs) and future floodplain developments. (FPDs)

As suggested by National Technical Working Group (NTWG) of TNMC to used development period to similar with Council Study only in 2020 and 2040. However, based on requirement from FMMT-MRCS focus more on 2060, therefore the scenario will study for all 3 development year but focus detail in year 2060.

Table 8 Table Details of Upstream Development (USD) and Floodplain Development (FPD) Scenarios

No	Year	Scenario name	Time series	USD scenario	FPD scenario
Impact of future Upstream and Floodplain Development on future flood					
1	2014	BSD-2014	CC-Baseline	USD-2014	FPD-2014
2	2020	BSD-2020	CC-Baseline	USD-2020	FPD-2020
3	2040	BSD-2040	CC-Baseline	USD-2040	FPD-2040
4	2060	BSD-2060	CC-Baseline	USD-2060	FPD-2060

Table 9 Assumption for USDs and FPDs in the NMK Basin

BSD-2014	BSD-2020	BSD-2040	BSD-2060
1. Upstream Developments (USDs)			
1.1 Land use change in upstream of NMK Basin			
Based on current situation year 2014	Assume no change between year 2014 / 2020	Assume land use change by increasing area of future field crop (economic agriculture) in upstream of Nam Mae kok, Nam Fang and Nam Lao. No information collected from Sector, therefore the consider of change will consider inside model by checking land use type and slope but limit change not over than 10%	Assume land use change by increasing area of future field crop (economic agriculture) in upstream of Nam Mae kok, Nam Fang and Nam Lao. No information collected from Sector, therefore the consider of change will consider inside model by checking land use type and slope but limit change not over than 20%
1.2 Flow change from Upper Mekong Basin (Based on Council Study, MRCS 2017)			
5 Chinese Existing Dams are in place (Manwan, Dachaoshan, Gongguoqiao, Xiaowan and Jinghong)	11 Chinese Dams will be in place in year 2020 (5 from BL2014, Nuazhadu, Miao Wei, Da Hua Qiao, Huang Deng, Li Di and Wu Nong Long)	12 Chinese Dams will be in place in year 2040 (11 from BDS1 Dev2020, and Tua Ba)	12 Chinese Dams will be in place in year 2060 (same as 2040)
2. Floodplain Development (FPDs)			
2.1 Urbanization of Chiang Rai			
Based on current situation year 2014	Assume change in year 2020 from Chiang Rai Urbanization expansion only inside city.	Assume change in year 2040 similar to year 2020 from Chiang Rai Urbanization expansion.	Assume change in year 2060 from Chiang Rai Urbanization expansion to East side as proposed in P-2060 development planning.
2.2 Floodplain Developments in Chiang Rai urban Area (Nam Korn – Lower Nam Lao)			
Based on current situation year 2014	Loss of 20% floodplain	Loss of 50% floodplain	Loss of 75% floodplain

SCENARIO OF CLIMATE CHANGE AND NEW PROPOSED WATER INFRASTRUCTURE

Description of scenario under climate change and new proposed water infrastructure is as follow:

NEW PROPOSED WATER INFRASTRUCTURE

Two proposed structure measurements were simulated for reduce impact of Future floodplain Development inside ISIS model comparing with BDS3-2060 with the name of SCN as below:

(1) BDS3-2060:

"BDS3-2060" is previous scenario of Upstream development (USD) and floodplain development (FPD) in year 2060. Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 75% flood storage over the NMK and definite upstream development in 2060.

(2) BDS3a-2060Flw:

"BDS3a-2060Flw" means "BDS3-2060" with Floodway in Nam Korn – Nam Lao. Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 75% flood storage over the NMK and definite upstream development in 2060 plus new proposed floodway in Nam Korn –Nam Lao.

(3) BDS3b-2060Bnk:

"BDS3b-2060Bnk" means "BDS3-2060" with Bank Protection in Lower Nam Kok. Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 75% flood storage over the NMK and definite upstream development in 2060 plus new proposed river bank in Lower Nam Kok.

CLIMATE CHANGE

Strong Climate Change scenario (GFDL-2060-RCP4.5) was selected for study impact of Future floodplain Development and Climate Change on Future Flood Behavior, comparing with "BDS3-2060" as detail below:

(4) BDS3c-2060CC:

"BDS3c-2060CC)" means "BDS3-2060" with Climate change. Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 75% flood storage over the NMK and definite upstream development in 2060 include impact from Climate Change.

(5) BDS3d-2060CCFlw:

"BDS3d-2060CCFlw" means "BDS3-2060" with Floodway in Nam Korn – Nam Lao and Climate change. Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 75% flood storage over the NMK and definite upstream development in 2060 plus new proposed floodway in Nam Korn –Nam Lao include impact from Climate Change.

(6) BDS3e-2060CCBnk:

"BDS3e-2060CCBnk" means "BDS3-2060" with Bank Protection in Lower Nam Kok and Climate change. Scenarios on Loss of flood storage through the urban expansion of Chiang Rai City and Loss of 75% flood storage over the NMK and definite upstream development in 2060 plus new proposed river bank in Lower Nam Kok include impact from Climate Change.

Summary of Scenario as present in Table.

Table 10 Table: Summary of Scenario

Scenario	Year				USD&FPD (Loss of flood storage, %)				Climate Change	New proposed structure	
	2014	2020	2040	2060	0	25	50	75		Flw	Bnk
BDS0-2014	O				O						
BDS1-2020		O				O					
BDS2-2040			O				O				
BDS3-2060				O				O			
BDS3cc-2060cc				O				O	O		
BDS3a-2060Flw				O				O		O	
BDS3b-2060Bnk				O				O			O
BDS3d-2060CCFlw				O				O	O	O	
BDS3e-2060CCBnk				O				O	O		O

3.5 CONCLUSION

From the previous analysis, national experts concluded that scenario C is selected to be preferred case (Green-Blue: city Agri-business to increase productivity). Green-Blue City of Chiang Rai with the idea of living with river or sustainable socio-economic development with climate change adaptation is the preferred way of Chiang Rai province and NMK sub-basin. However, future scenarios are developed to illustrate the impact of (1) Upstream development (USD) and floodplain development (FPD); (2) Climate change and (3) New proposed water infrastructure. Flood level frequency curve, damage probability curve and annual average damage under these development scenarios are calculated and illustrated in the next chapter.

CHAPTER 4

FUTURE FLOOD DAMAGE RELATIONSHIPS (TASK 5)

4.1 INTRODUCTION

This chapter is concentrated in Task 5 "Formulation of existing and future flood damage estimation relationships" which uses scenarios and assumptions developed from Task 4 "Assessment of possible future flood behavior under conditions of inferred future climate change, future upstream developments (dams) and future floodplain development" in the previous chapter. The main output of this chapter is flood damage curve in the present condition to show the relationship between water level and economic damage. Then, this developed relationship will be used to simulate future economic relationship.

4.2 IMPACT ASSESSMENT LOCATIONS

FLOOD IMPACT AREA

Based on previous study (Kittipong, 2019) and IS-Phase 1 that possible flood area in NMK are (1) locating between Nam Korn and lower Nam Lao (Urban Flooding) as shown in following figure and (2) Flooding at the downstream reach of Nam Mae Kok (Rural Flooding) especially the last 50 km length occur regularly by the influence of high water level and back water from Mekong river.

FLOOD REPRESENTATIVE LOCATION

Base on Initial Study phase I, The station at the Lao River crossing with the Road no. 1020 was selected for this study as it experiences representative flooding characteristics at Mueang Chiang Rai District. Similarly, a station of the Kok River near Wat Santhat Asoka Ram Temple in Chiang Saen District, 11 km upstream from the river mouth is chosen for representing flooding condition of the Chiang Saen District. The location of representatives for Chiang Rai and Chiang Saen for identified flood behaviour as shown in following figure. Two Locations for impact assessment Location as below

No	Location	UTM grid	Cross Section
1	RPL1-Representative of flooding at Muang Chiang Rai District	47Q 588466 mE 2195837 mN	LAO-12 on Lao River
2	RPL2-Representative of flooding at Chiang Saen District	47Q 613811 mE 2235162 mN	KOK-79 on Kok River

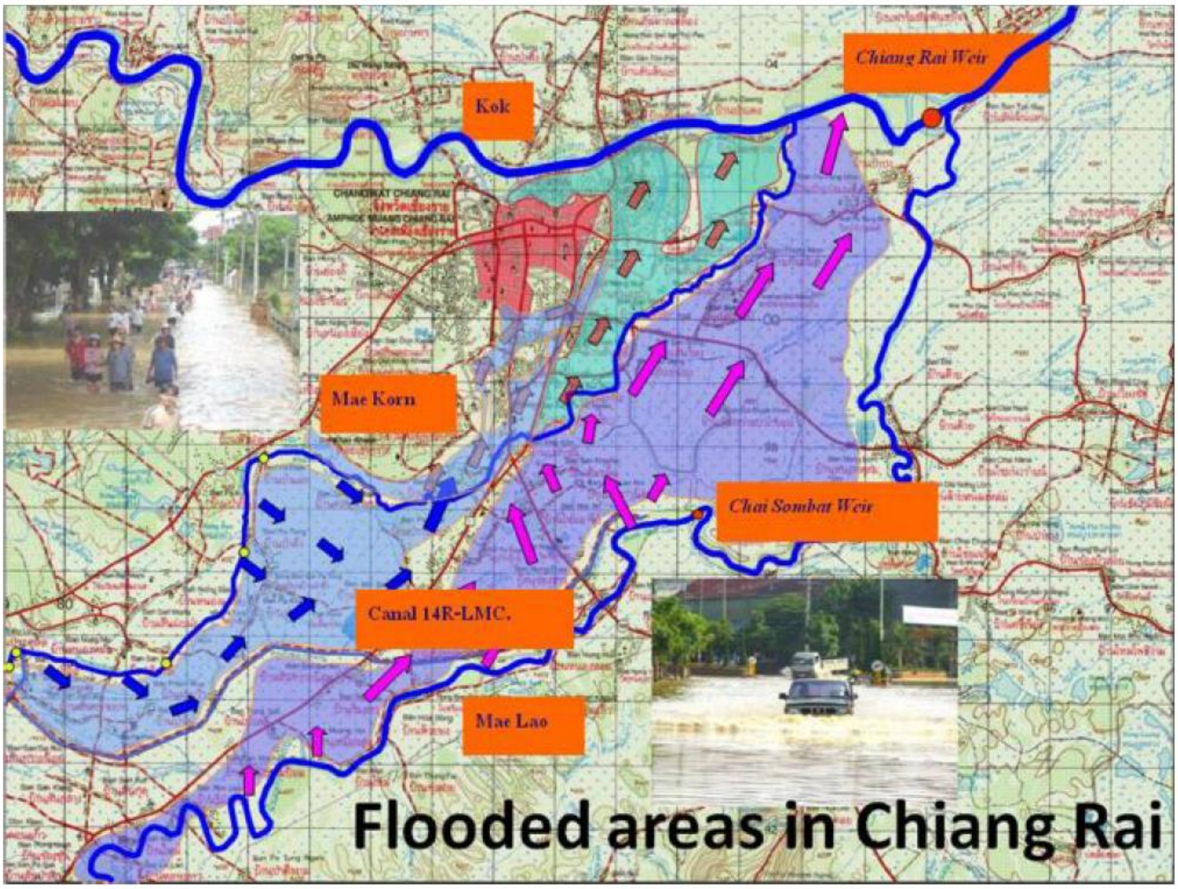

Figure 18 The Flooded area in Nam Mae Kok River Basin
(Flood coverage, flood ways and flood direction in Nam Korn-Nam Lao floodplain, after Chiang Rai Municipality 2006)

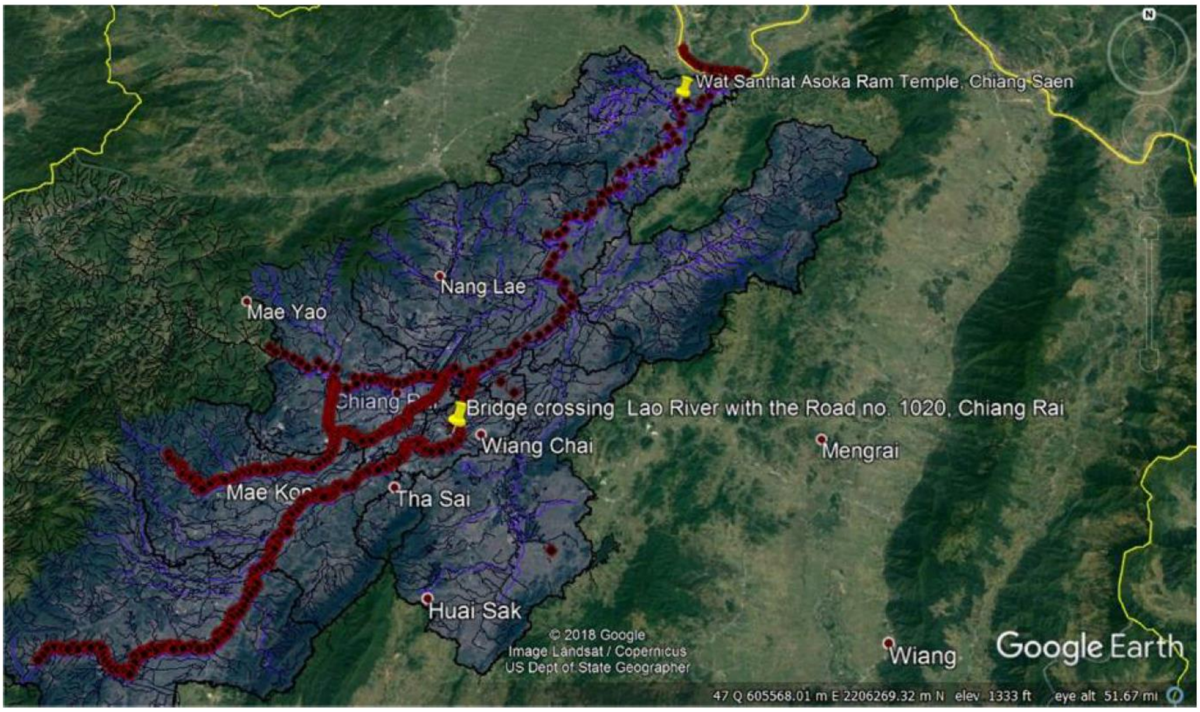

Figure 19 The location of flooding representatives for Chiang Rai and Chiang Saen

4.2 FLOOD SIMULATION

Flood damage curve is developed from two main data: (1) annual maximum water level and (2) economic damage. To analyze relationship of flood damage in the past to present, we use exiting observed data. However, in future scenarios, flood damage is simulated by using calculation results from flood model.

THE FLOOD SIMULATION MODELS

The SWAT, IQQM and ISIS models of the MRC DSF/MRC Toolbox will be used to assess the impacts of future USDs and likely FPDs, separately and severally, on future flood behavior in the FFAs generally and in nominated hotspots particularly:

1) The regional models will be modified to reflect the USD and FPD conditions of nominated future basin development scenarios, and then be used to simulate future flood behavior on a basin wide basis.
2) The local SWAT and ISIS models of the Nam Mae Kok basin will be modified to reflect the USD and FPD conditions of nominated future basin development scenarios and will then be used to simulate future flood behavior in the FFAs and hotspots.

3) It is proposed that the selected USD scenario and the IFFPD scenario will be adopted to define a 'benchmark FBD scenario' and agreed by National experts and Working groups.
4) Other USDs and FPDs scenarios will be analyzed and their impacts on future flood behavior, flood risk and flood damage will be assessed against the benchmark FBD scenario.

BASELINE NMK-SWAT MODEL

The detail of SWAT –ISIS model for Nam Mae Kok was document in "Calibration Report; Calibration of Local SWAT, IQQM and ISIS models for Nam Mae Kok Basin and FFA, Ornanong, 2018), Below will summary only main point that used for Scenario development application.

SWAT model is a physical based hydrologic model which requires physical based data: Digital Elevation Model (DEM), Land use and Soil Classification. For the Nam Mae Kok River (NMK) Basin a local SWAT model has been reformulated and calibrated for this flood study based on the regional model version. SWAT model was selected and applied in Nam Mae Kok to simulate the subbasin flow in current condition, future climate change condition and/or land use change condition. The results of SWAT model mainly were used as inflow of the other models like IQQM and ISIS model for the simulation of water use and water level in channel and floodplain area.

The SWAT model was reformulated and recalibrated using SWAT 2012 and extends weather data to covering period 1985-2014, then continued to simulate for year 1985 – 2014 (30 years).

(1) Data for model set up

The data for reset-up SWAT model based on Regional model with more sub-basin for further link to existing ISIS in Nam Mae Kok model as below:

(1.1) Spatial Data:

- Digital Elevation Model (DEM): The data source is the 1:50,000 scale American topographic maps and available on 50 m grid.

- Land cover map: Originally based on the MRC land use map, there are 44 land use types covering the entire Kok River Basin. Similar land use types were grouped and presented into one type; finally a total number of 24 land use types were obtained. About 70% of the basin area still be covered by forest

(EHCD+FRSL+MEDH) and agricultural area coverage is around 18% (FCRP+PDDY+ORCD).

- Soil map: Based on MRC soil classification map, 23 soil types were classified covering the entire Kok River Basin. There are 3 major soil classes in the basin including SC, Ao and Nh with the percent of coverage areas relative to the basin area about 44.3%, 21.4% and 9.0% respectively.

(1.2) Time series data: All available data at MRCS have been collected from MC including from line agency in Thailand such as Department of water resource (DWR), Thai Meteorological Department (TMD) and Royal Irrigation Department (RID) from year 1985-2014.

- Climatic data: Min and Max Temperature, Relative Humidity, Solar Radiation and Wind speed from year 1985 – 2014 at station Chiang Rai (199907) and Chiang Saen (200002)
- Daily Rainfall data from year 1985 – 2014; Areal precipitation from MRCS database (Area 2: Chiaeng Saen – Luang Prabang) that analysis from MQUARD with more regional station was used e.g. rainfall at sub basin 27, 36, 41, 44, 51, 53, 63 and combine with areal precipitation estimated from TMD and DWR.
- Daily Hydrological data from year 1985 – 2014 for calibrate and validate model.

CALIBRATION RESULT

The calibration result (1985-2008) and validation result (2009-2014) for all calibration stations have COE higher than 0.30 and different of Simulation flow and Observed volume ratio are between 0.09–0.25 (-9% - 25%), therefore the model can use for further application.

The 2 key stations are: Nam Mae Kok at Ban Pong Na Kham and Nam Lao at Ban Pong Pu Fuang were applied as upstream boundary in ISIS model.

- Nam Mae Kok at Pong Na Kham has COE around 0.71 with Volume ratio around 1.03 for calibration period (1985-2008), COE around 0.77 with Volume ratio around 0.99 for validation period (2009-2014)
- Nam Lao at Ban Pong Pu Fuang has COE around 0.45 with Volume ratio around 1.12 for calibration period (1985-2008), COE around 0.47 with Volume ratio around 1.19 for validation period (2009-2014)

For more detail, please see Task 4, Ornanong, 2018.

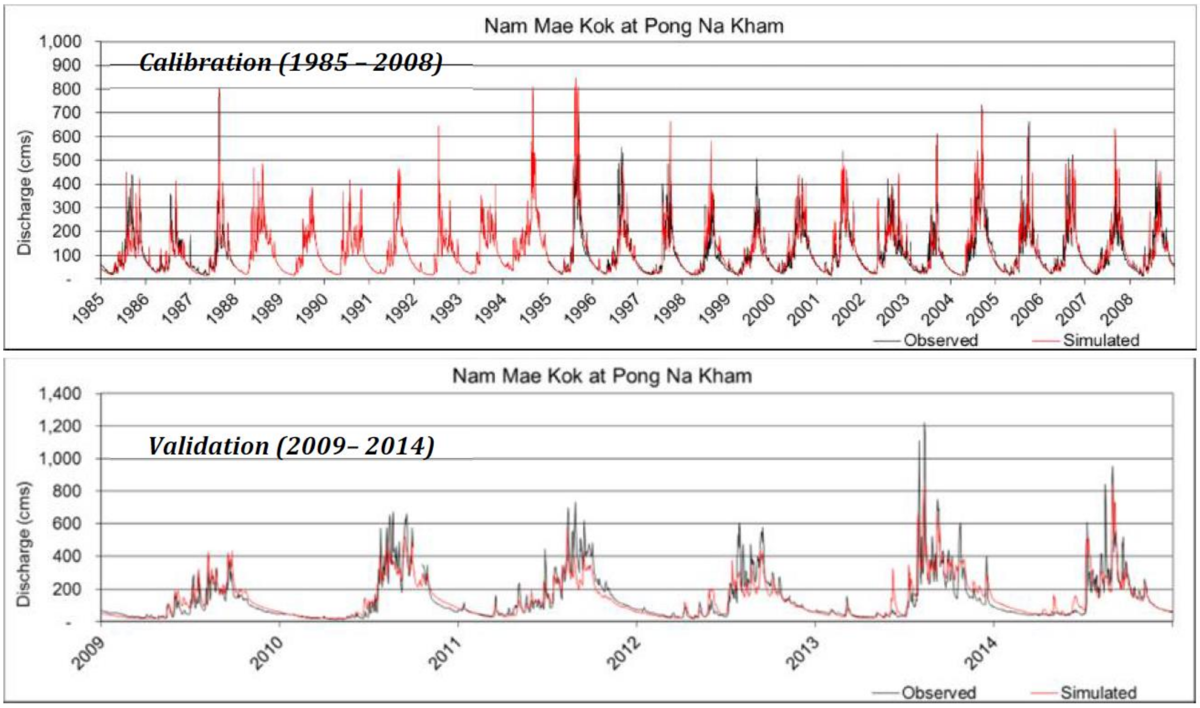

Figure 20 Calibration and Validation result for Nam Kok and Nam Lao

4.3 FLOOD DAMAGE CURVES

FLOOD LEVEL DATA

Flood level used in this analysis is collected from two sources:

1. Past flood level from MRCS and National Line agency from during year 1985 to 2014;
2. Analysis flood level from the SWAT model and ISIS model during year 2014 to 2060. (for more detail, please see Task 4, Ornanong, 2018)

Two locations for impact assessment location are as follow

1. Representative of flooding at Muang Chiang Rai District location with UTM grid Cross Section of 47Q 588466 mE 2195837 mN and cross section of LAO-12 on Lao River
2. Representative of flooding at Chiang Saen District location with UTM grid Cross Section of 47Q 613811 mE 2235162 mN and cross section of KOK-79 on Kok River

Flood frequency analysis of above two stations on Nam Mae Kok and Nam Lao was produce in recurrence interval 2, 5, 10, 15, 20, 25, 30, 50 and 100 using result from simulation period year 1985 – 2014 as shown.

Table 11 Annual Maximum water level for BDS for various return periods from Simulation 1985 – 2014

Location	Return Period, Yrs.	BL-2014	BDS1-2020	BDS2-2040	BDS3-2060
Muang, Chiang Rai	2	391.32	391.39	391.42	391.54
	5	391.81	391.87	391.94	392.08
	10	392.11	392.16	392.27	392.42
	20	392.38	392.42	392.57	392.74
	25	392.46	392.50	392.66	392.83
	50	392.70	392.74	392.94	393.12
	100	392.94	392.97	393.22	393.40
	200	393.16	393.19	393.48	393.68
Chiang Saen	2	364.63	364.69	364.71	364.74
	5	365.22	365.23	365.24	365.26
	10	365.58	365.55	365.56	365.58
	20	365.91	365.85	365.86	365.86
	25	366.02	365.94	365.94	365.95
	50	366.32	366.21	366.21	366.22
	100	366.62	366.47	366.47	366.47
	200	366.90	366.72	366.71	366.72

Source: Task 4, Ornanong, 2018

Flood Level Frequency Curve

Flood Level Frequency Curve is defined as relationship between annual peak flood levels and annual exceedance probabilities. The annual maximum water level data in the previous sector is illustrated with the return period or annual recurrence interval and shown in **Figure 21** and **Figure 22** for Mueang Chiang Rai District and Chiang Saen District, respectively.

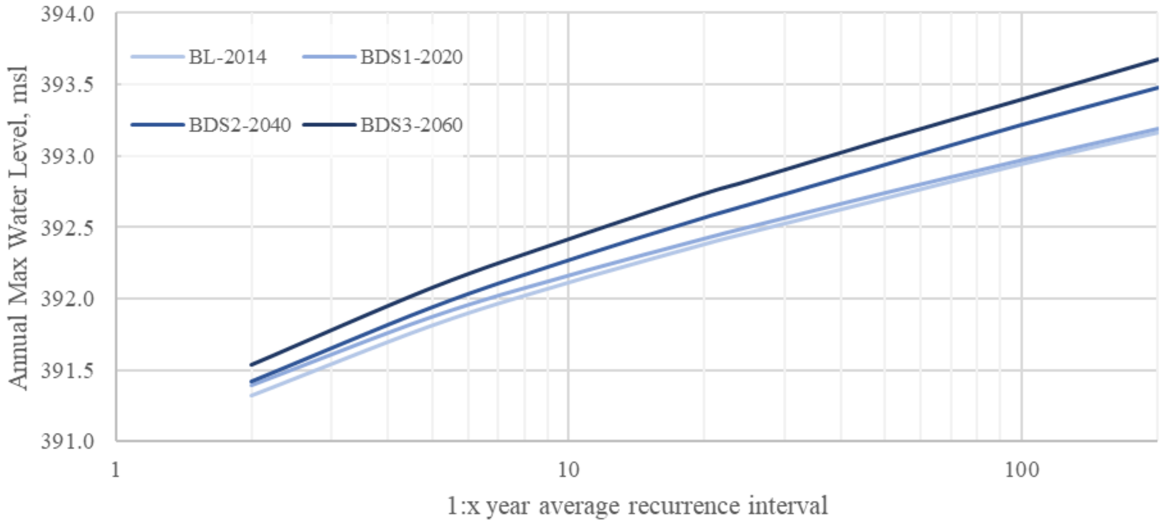

Figure 21 Flood level frequency curve in Muang Chiang Rai
(Source: Task 4, Ornanong, 2018)

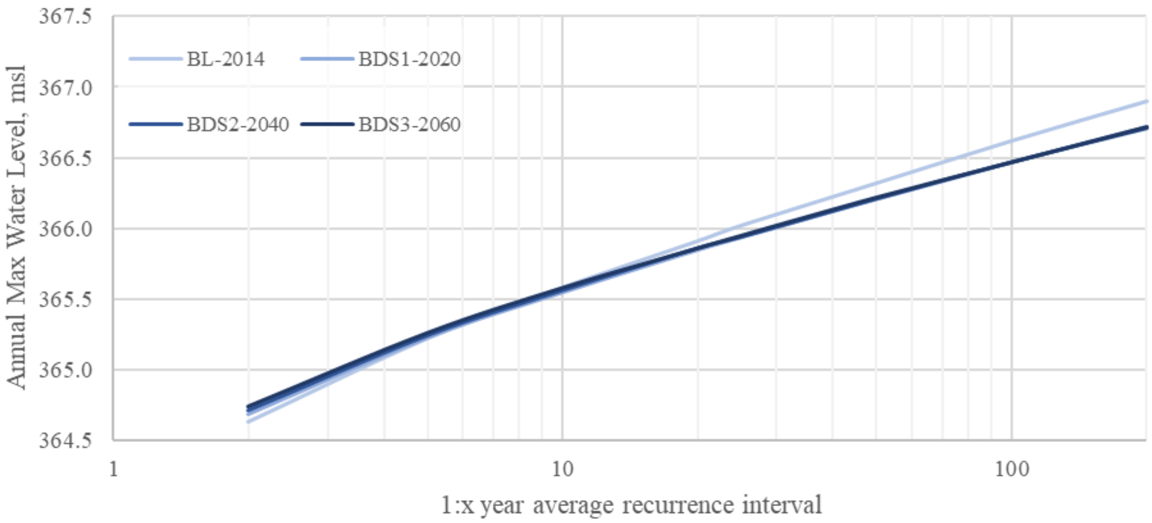

Figure 22 Flood level frequency curve in Chiang Saen
(Source: Task 4, Ornanong, 2018)

FLOOD DAMAGE

Two approaches are presented for damage curve estimation: (1) **Top-Down Approach** with sectoral damage to a flood level at an impact assessment location (IAL) and (2) **Bottom-Up Approach** with GIS, land use and flood surface layers to calculate flood depths and damage impacts per grid cell. In this report, we use the Top-Down Approach because of data limitation.

Flood damage curve or damage function is defined as relationship between water level and damage for a given sector. Flood damage data is collected from Department of Disaster Prevention and Mitigation. Relationship of flood damage and annual maximum water level from last section is analyzed. Analysis result of flood damage curves in each sector (agriculture, non-agriculture (housing and infrastructure)) and in each area (Mueang Chiang Rai District and Chiang Saen District) are showed in **Figure 23** to **Figure 28**.

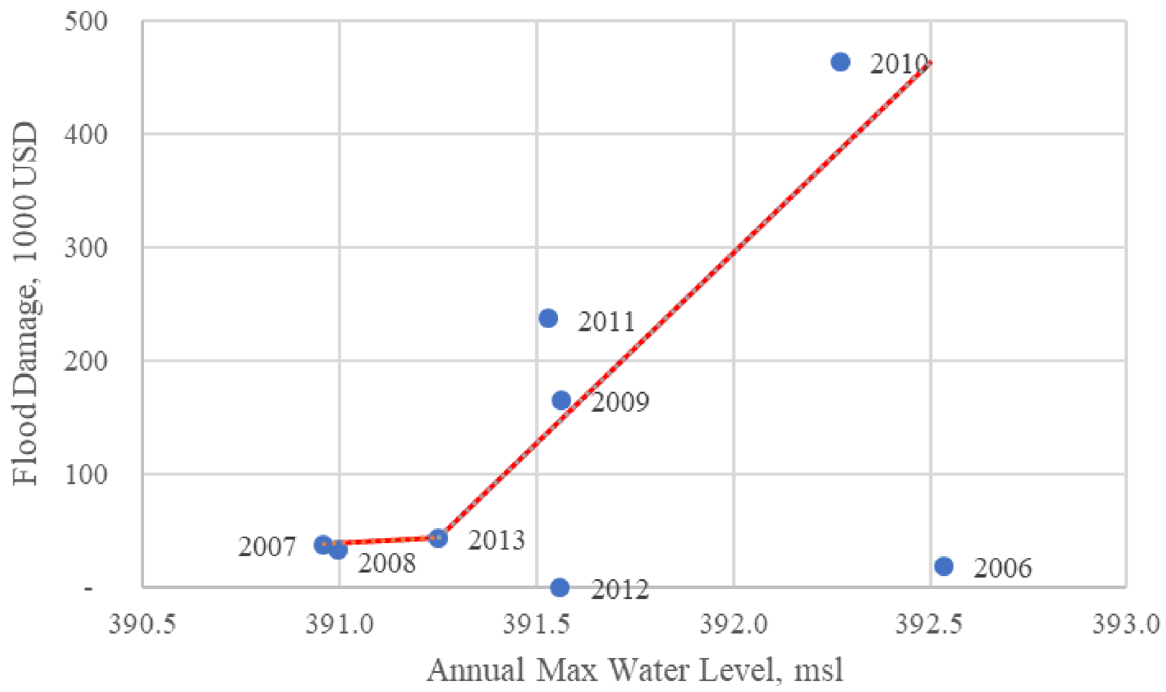

Figure 23 Relationship between flood damage and annual maximum water level in Mueang Chiang Rai District

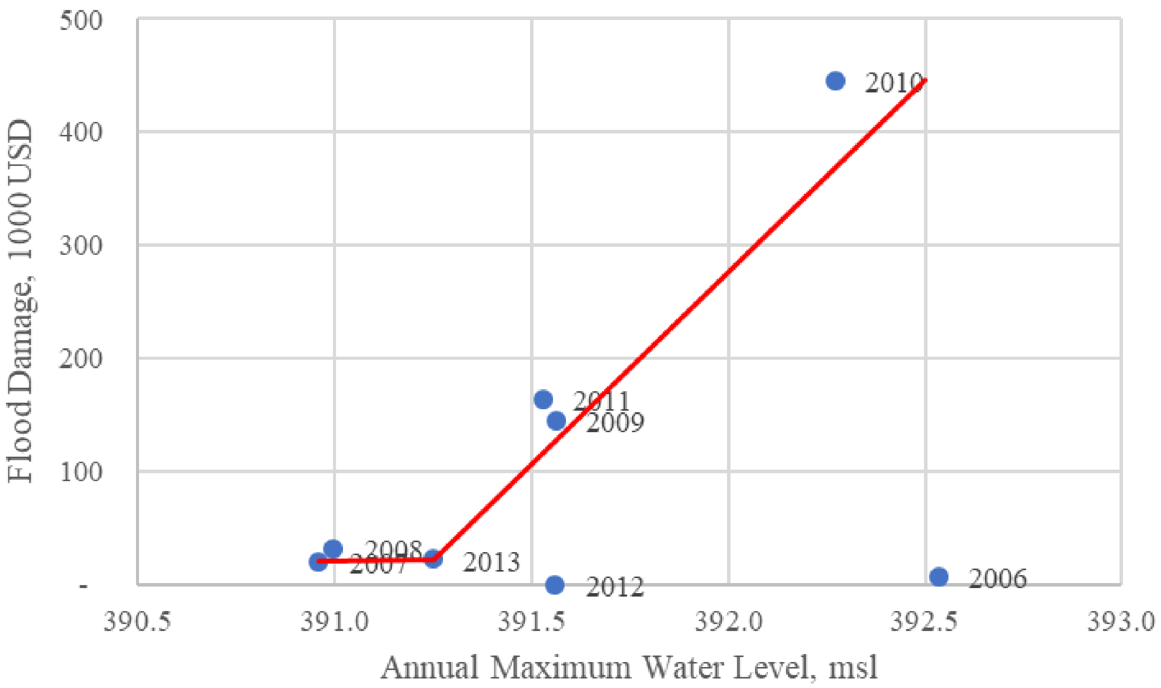

Figure 24 Relationship between agricultural flood damage and annual maximum water level in Mueang Chiang Rai District

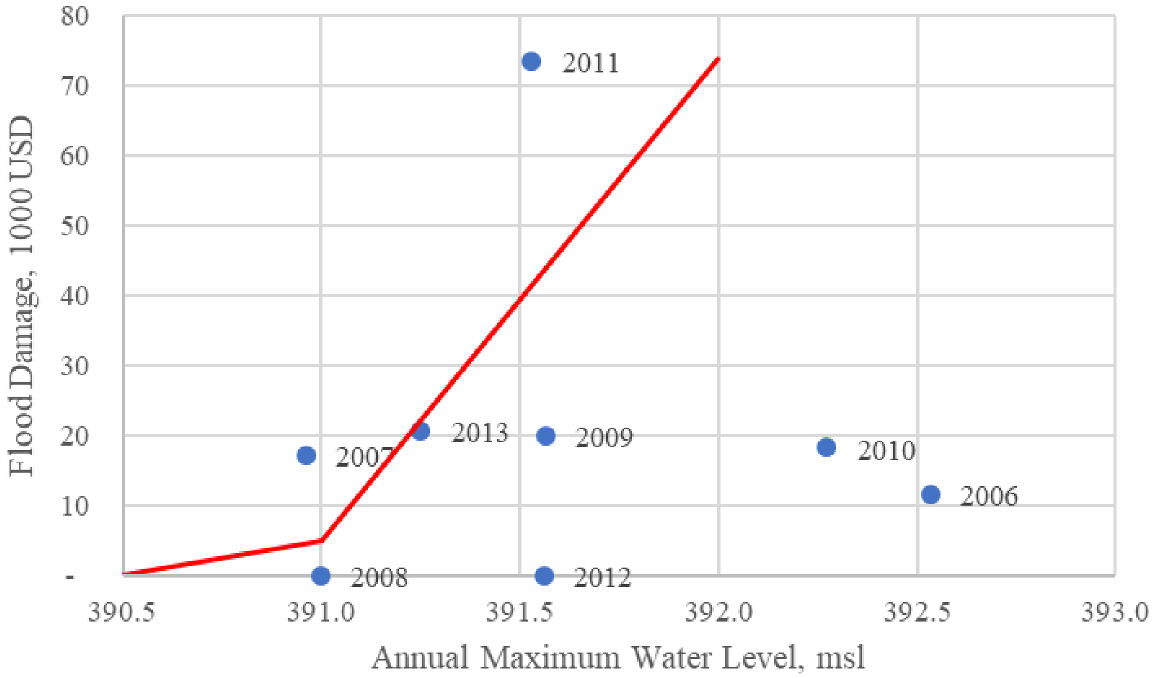

Figure 25 Relationship between non-agricultural flood damage and annual maximum water level in Mueang Chiang Rai District

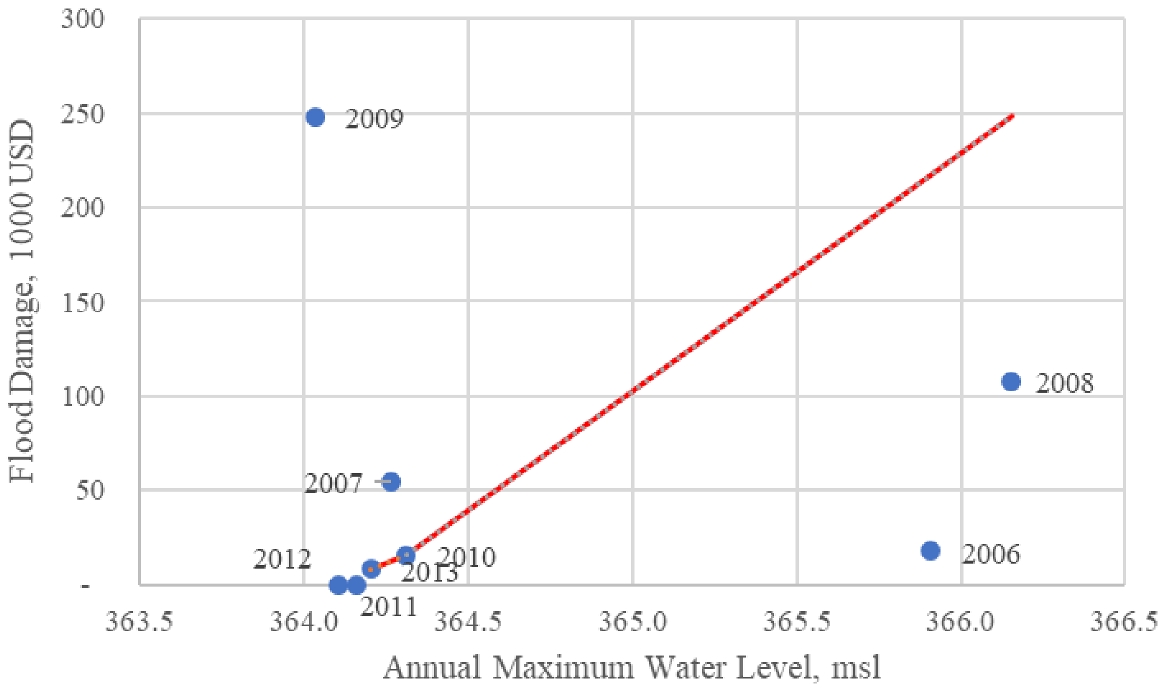

Figure 26 Relationship between flood damage and annual maximum water level in Chiang Saen

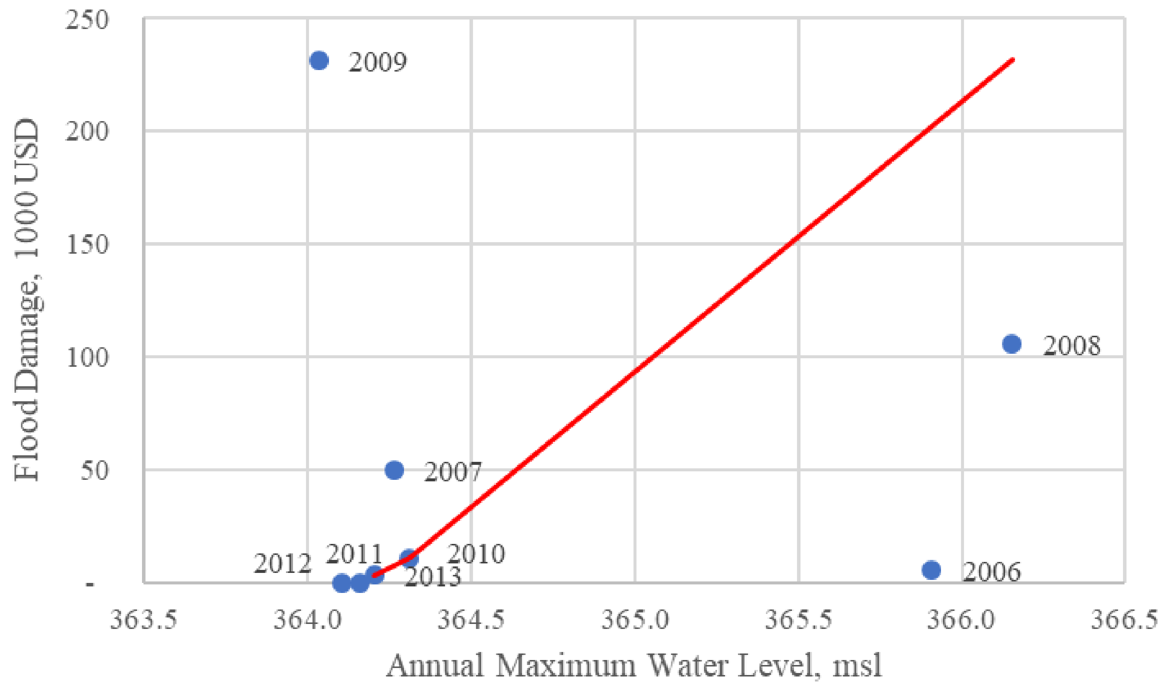

Figure 27 Relationship between agricultural flood damage and annual maximum water level in Chiang Saen

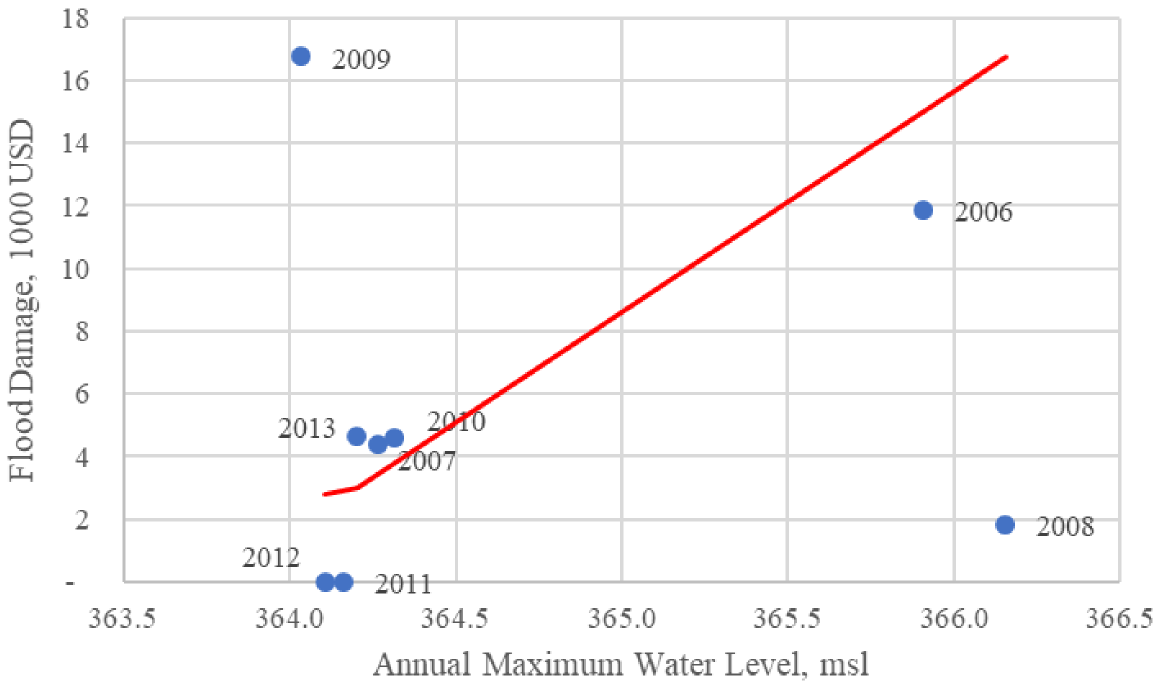

Figure 28 Relationship between non-agricultural flood damage and annual maximum water level in Chiang Saen

FLOOD DAMAGE PROBABILITY CURVE

Risk is a function of consequence and likelihood. In this report, risk, consequence and likelihood are defined as flood damage probability curve, damage curve and flood level frequency curve, respectively. Risk or flood damage probability curve can be formulated as follow;

$$\text{Risk} = \text{Consequence} * \text{Likelihood}$$

$$(\text{Damage} / \text{Probability}) = (\text{Damage} / \text{Water level}) * (\text{Water level} / \text{Probability})$$

Flood damage probability curve is defined as relationship between flood damage and annual exceedance probability. From collected data of water level in each return period and economic damage, we can generate flood damage probability curve as follow;

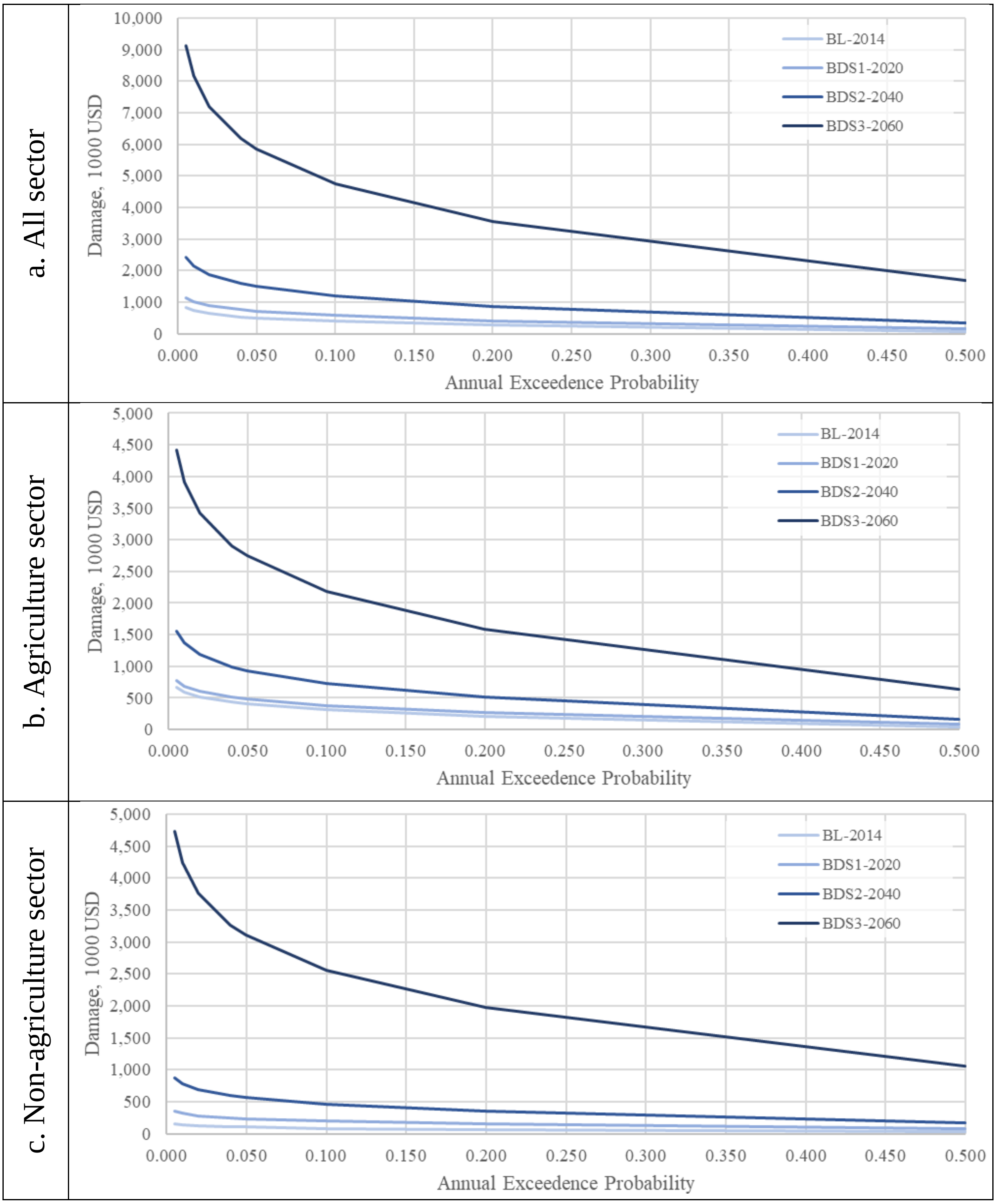

Figure 29 Flood Damage Probability Curve: Muang, Chiang Rai

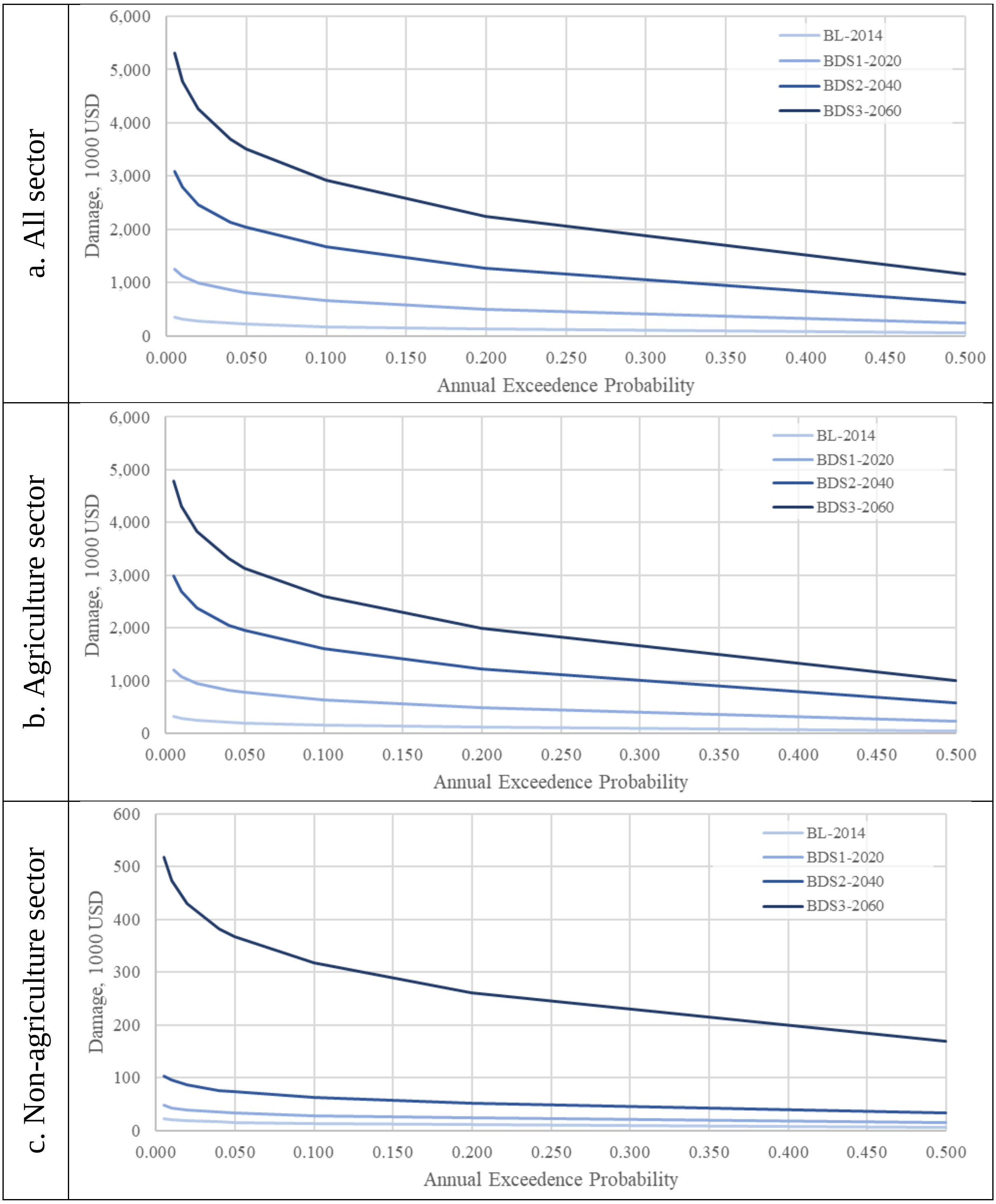

Figure 30 Flood Damage Probability Curve: Muang Chiang Saen

4.4 SOCIO-ECONOMIC FACTORS

Socio-economic development is one of the important drivers for future flood damage. Economic scenario is applied with physical scenario in previous section. Future foresight of development in agricultural and non-agricultural sectors is designed and illustrated in **Table 12**. The detail of each economic scenario is shown in the following section.

Table 12 Conclusion of economic scenario

Scenario	Detail	Assumption
Scenario 1 Business as Usual (A1N1)	Integration of - socio-economic scenario in agriculture “A1”: farmer uses technology and innovation for rice production; - socio-economic scenario in housing and infrastructure “HI1” under population and GDP per capita in the future.	1. Rice is mainly considered in this area. 2. The cultivated area of crop in the future is assumed to change as the same rate as the past 3. The productivity or yield of rice (kg/ha) in the past of Japan and Thailand is compared to illustrate the difference of productivity and to use in this study. 4. The price of rice in Thailand in the future is as same growth rate as the past.
Scenario 2 Greater value-added Rice (A2N1)	the same structure as scenario 1 but socio-economic scenario in agriculture “A2” means farmer use technology and innovation for rice production concentrated in organics way to increase value added of rice.	1. The price of organic rice in Thailand in the future is as same growth rate as the past.

AGRICULTURAL SECTOR

In this analysis, year 2020, 2040 and 2060 are considered as events in the future. For example, in case of year 2020 and in each district, the Agricultural Damage Probability Curve (ADPC2014/2020) is generated using the previous 2014 Agricultural Damage Curve (ADC2014) and the 2020 Flood Level Frequency Curve (FLFC2020). This curve is generated by using the following formula:

$$V2020 = sum\ (Ac \times Yc)$$

$$V2014 = sum\ (Ac \times Yc)$$

$$AF1 = v2020 / v2014$$

$$ADPC2020 = AF1 \times ADPC2014$$

where

v is value of each crop type in each area

A is area

Y is unit price per area

c is crop type

AF1 is ratio of value of each crop type in each area between 2020 and 2014

ADPC is agriculture damage probability curve

NPV2020: assume discount rate of x% over 5 years, AAD varies linearly over than time

For a given crop at 2014 and 2020, the farm-gate value of a crop can be represented by:

$$FGVc = Ac \times Pc \times FGPc$$

Where

FGVc is the farm-gate value (USD) of crop c,

Ac is the cultivated area of crop c (ha),

Pc is the productivity of crop c (kg/ha), and

FGPc is the farm-gate price of crop c (USD/kg).

AGRICULTURAL PRODUCTION AND PRICING

Agricultural production and pricing are considered under 2 scenarios:

Scenario 1 named "*A1N1*" means integration of (a) socio-economic scenario in agriculture "A1": farmer uses technology and innovation for rice production and

(b) socio-economic scenario in non-agriculture (housing and infrastructure) "N1" under population and GDP per capita in the future.

Scenario 2 named "*A2N1*" is the same structure as scenario 1 but socio-economic scenario in agriculture "A2" means farmer use technology and innovation for rice production concentrated in organics way to increase value added of rice.

Based on the previous issue, the cultivated area of crop c (ha), the productivity of crop c (kg/ha), and the farm-gate price of crop c (USD/kg) in the past are analyzed and estimated in the future under following assumptions.

1. Rice is mainly considered in this report because of food security.

2. The cultivated area of crop in the future is assumed to change as the same rate as the past. In this study, we assume that the ratio of cultivated area of rice in 2020, 2040 and 2060 comparing with 2014 is 0.9, 0.9 and 0.9 respectively for food security.

3. The productivity or yield of rice (kg/ha) in the past of Japan and Thailand is compared to illustrate the difference of productivity. Yield of Japanese rice is greater than Thai rice approximately 2.33 times (**Figure 31.**). In this report, it is assumed that the yield of thai rice in 2020 is the same as 2014; however, in the future it should be increased to 2.33 times comparing with the present by technology and innovation used in Japan. In this study, we assume that the ratio of productivity or yield of rice in 2020, 2040 and 2060 comparing with 2014 is 1, 1.3 and 2 respectively.

4. The price of rice in Thailand from the past is shown in **Figure 32**. The data shown that in last 10 years, rice price is fluctuated from 180 to 230 USD per ton of rice. In this report, the price of rice is assumed to increase 1.3 times (related to the data in the past). In this study, we assume that the ratio of price of rice in 2020, 2040 and 2060 comparing with 2014 is 1.3, 1.3^2 or 1.7 and 1.3^4 or 2.9 respectively.

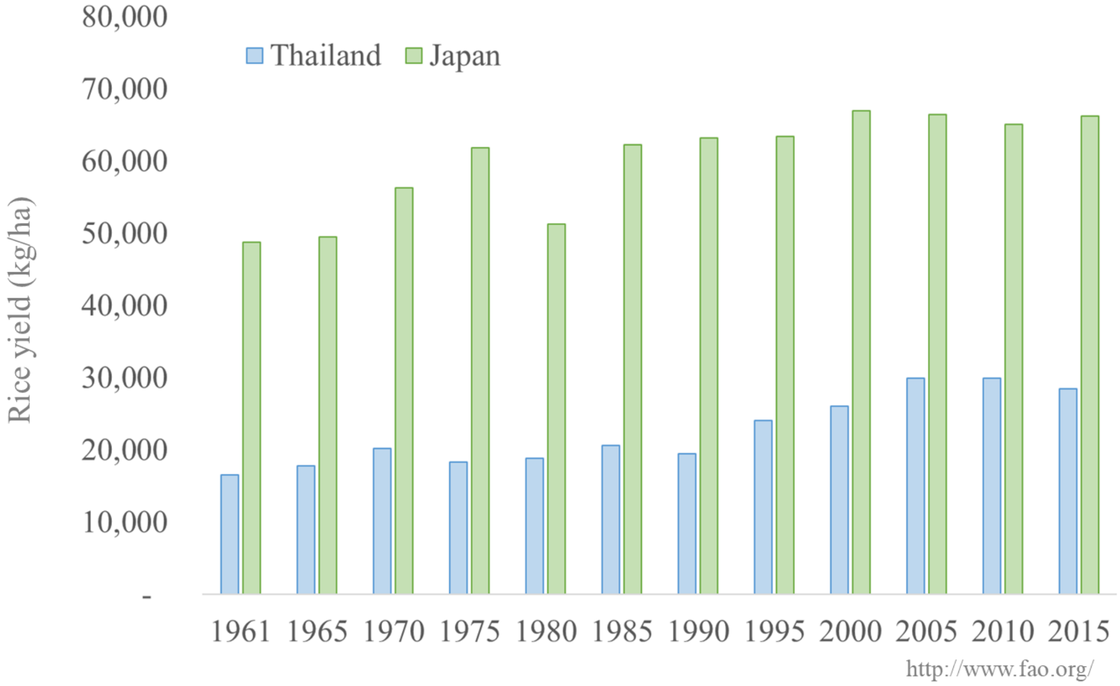

Figure 31 Rice yield (kg/ha)

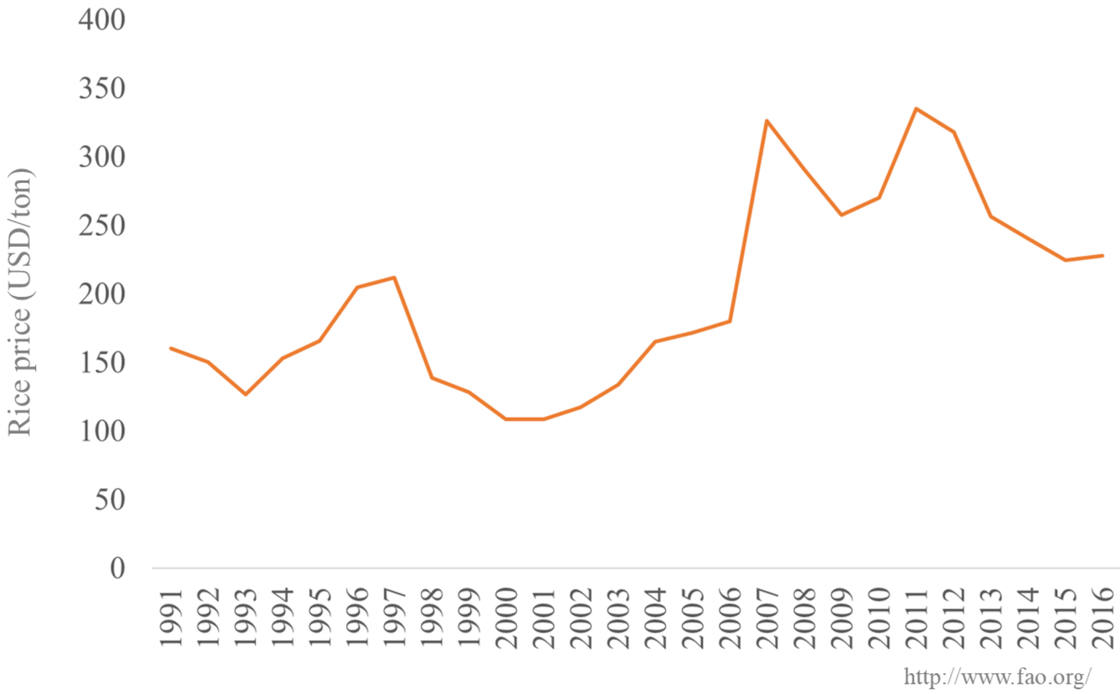

Figure 32 Rice price (USD/ton)

Based on these assumptions, we can conclude as follow;

Scenario 1: the ratio of the farm-gate value (USD) of rice of year 2020 and 2014 can be calculated as

$$FGVc(2020/2014) = Ac(2020/2014) \times Pc\,(2020/2014) \times FGPc(2020/2014)$$
$$= 0.9 \times 1.0 \times 1.3 = 1.14$$
$$FGVc(2040/2014) = Ac(2040/2014) \times Pc(2040/2014) \times FGPc(2040/2014)$$
$$= 0.9 \times 1.3 \times 1.7 = 1.99$$
$$FGVc\,(2060/2014) = Ac(2060/2014) \times Pc(2060/2014) \times FGPc(2060/2014)$$
$$= 0.9 \times 2.0 \times 2.9 = 5.22$$

Scenario 2: the ratio of the farm-gate value (USD) of rice caused by organic farming to increase value of product. In this study, we assume that the ratio of price of rice in 2020, 2040 and 2060 comparing with 2014 is 4.0, 10 and 16 respectively. It is also assumed that the price will increase to 10 times in 2040 and keep constant growth rate to 2060. Some national experts recommended this because of uncertainty in the long period. This scenario mainly shows the impact of rice price.

$$FGVc(2020/2014) = 1.0 \times 1.0 \times 4.0 = 4.0$$
$$FGVc(2040/2014) = 1.0 \times 1.0 \times 10 = 10$$
$$FGVc(2060/2014) = 1.0 \times 1.0 \times 16 = 16$$

This ratio will be used as the input for calculation of damage curve.

NON-AGRICULTURAL SECTOR (HOUSING AND INFRASTRUCTURE)

In this part, year 2020, 2040 and 2060 are considered as events in the future. For example, case of year 2020 and each district, the housing and infrastructure (HI) Damage Probability Curve (HIDPC2014/2020) is generated using the 2014 damage curve (HIDC2014) and the 2020 Flood Level Frequency Curve (FLFC 2020). This curve is generated by using the following formula:

$$HIF1 = Pop2020 / Pop2014$$

$$HIF2 = GDPC2020 / GDPC\ 2014$$

$$HIDPC2020 = HIF1 \times HIF2 \times HIDPC2014$$

Where

HIF1 is ratio of number of population between 2020 and 2014

Pop is number of population

HIF2 is ratio of GDP per capita between 2020 and 2014

GDPC is GDP per capita

NPV2020: assume discount rate of x% over 15 years, AAD varies linearly over than time

POPULATION AND GDP PER CAPITA

Population and GDP per capita in the future is named as "HI1" in each scenario. For example; scenario 1 named "2020A1HI1" means integration of (a) socio-economic scenario in agriculture "A1" farmer use technology and innovation for rice production and (b) socio-economic scenario in housing and infrastructure "HI1" under population and GDP per capita in the future.

POPULATION

In Thailand, the growth rate of population is decreasing as shown in **Figure 33**. Aging society is the main issue resulting in low rate of labor to generate income.

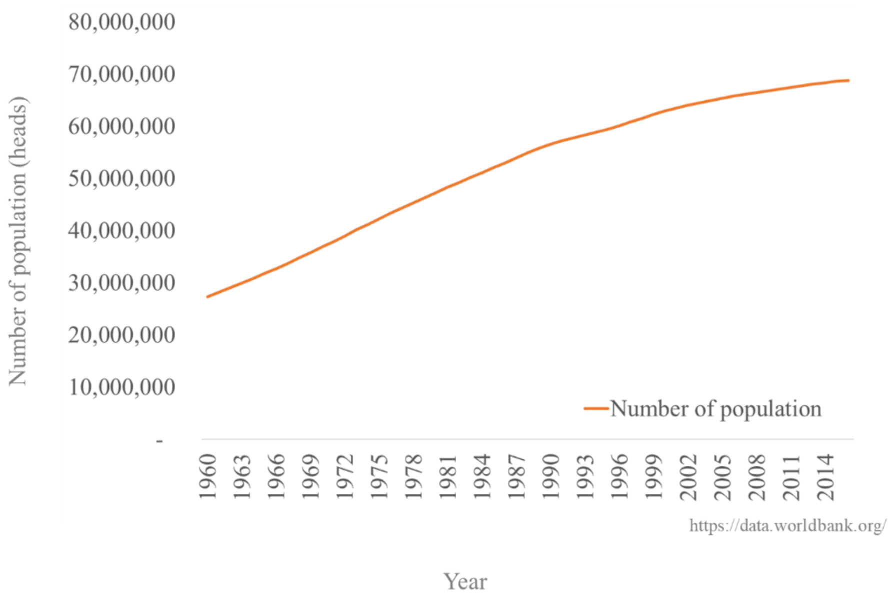

Figure 33 Number of population: Thailand (heads)

In Chiang Rai province, the number of population is decreasing from the past to present. This causes difficulty in income production and GDP. In this report, it is assumed that the growth rate of population from present to 2020 is the same rate as the past (**Figure 34.**) . Based on this assumption, population will be approximately 1,022,000 heads in 2020. This means the ratio of population in 2020 and 2014 or *HIF1* is 1,022,000 / 1,128,000 or 0.90. In this study, we assume that the ratio of population in 2020, 2040 and 2060 comparing with 2014 is 0.9, 0.9^2 or 0.8 and 0.9^4 or 0.64 respectively.

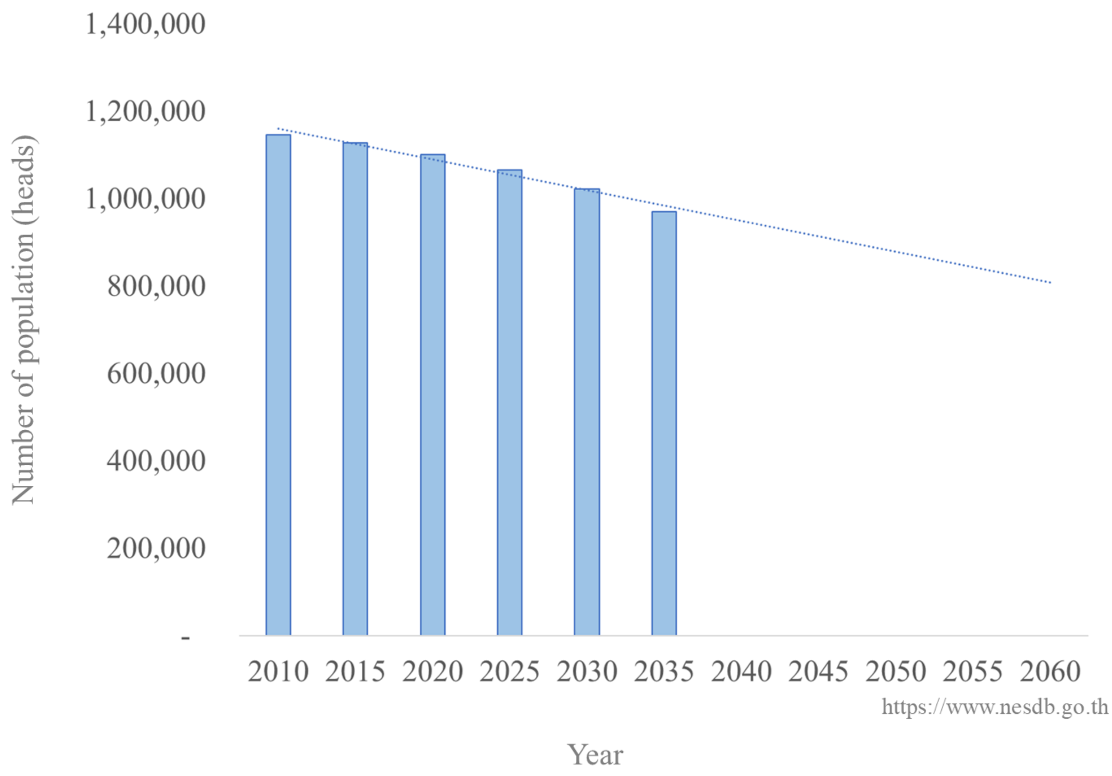

Figure 34 Number of population: Chiang Rai Province (heads)

GDP PER CAPITA

Government of Thailand declared national policy named "Thailand 4.0" to overcome middle income trap and become developed country. Based on this issue, target of GDP per capita is set from 6,000 in present to be 15,000 USD per capita in 2020 (**Figure 35**). In this report, it is assumed that Thailand is keeping this target until year 2060. Based on this assumption, GDP per capita will be approximately 12,000 - 15,000 USD per capita in 2020. This means the ratio of GDP per capita in 2020 and 2014 or *HIF2* is 15,000 / 6,000 or 2.5. We also assume that the ratio of GDP per capita in 2020, 2040 and 2060 comparing with 2014 is 2.5, 2.5^2 or 6.25 and 2.5^4 or 39 respectively.

Based on the previous issues, the formula can be shown as follow;

$$HIDPC(2020/2014) = 0.9 * 2.5 = 2.2$$

$$HIDPC(2040/2014) = 0.8 * 6.25 = 5.0$$

$$HIDPC(2060/2014) = 0.64 * 39 = 25.0$$

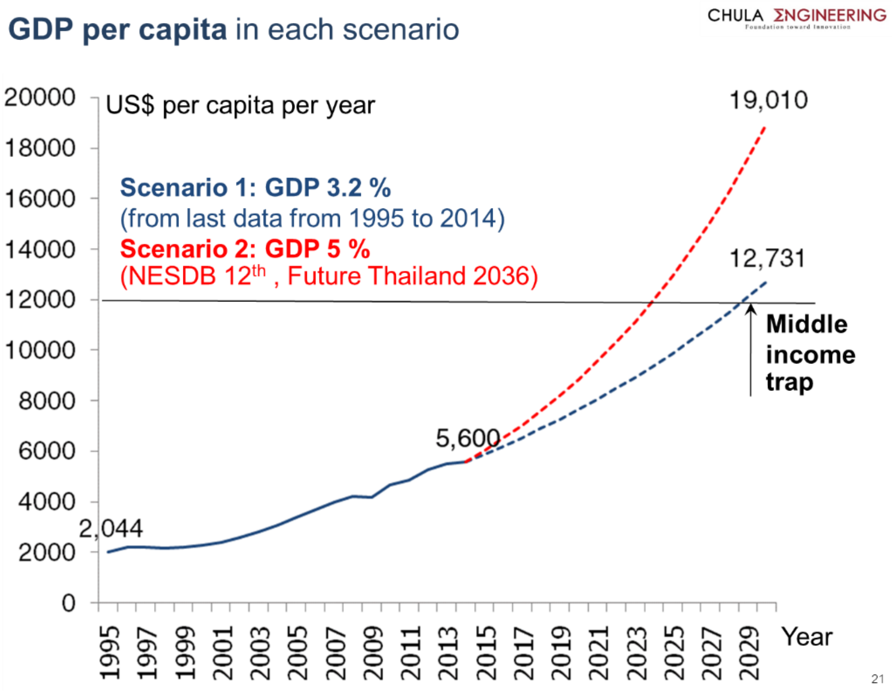

Figure 35 GDP per capita: USD per capita

Table 13 Conclusion damage multiplier in each economic scenario

Scenario	Sector	Physical scenario			
		BL-2014	**BDS1-2020**	**BDS2-2040**	**BDS3-2060**
Scenario 1(A1N1)	Agri	1.00	1.14	1.99	5.22
Business as Usual	Non-agri	1.00	2.27	5.00	25.00
Scenario 2 (A2N1)	Agri	1.00	4.00	10.00	16.00
Greater value-added Rice	Non-agri	1.00	2.27	5.00	25.00

4.5 CONCLUSION

Construction of future flood damage relationship has been successful. Physical scenarios (1. upstream and floodplain development and 2. climate change in the future) and economic scenarios (business as usual and greater value-added rice) are generated to calculate flood risk in the next chapter.

CHAPTER 5

FUTURE FLOOD DAMAGE (TASK 6)

5.1 INTRODUCTION

In this chapter, task 6 of the initial studies project is concentrated. Flood damage under future scenarios is calculated and presented as Flood Damage Probability Curve. Average Annual Damage (AAD) and Net Present Value (NPV) of AAD are also illustrated for risk assessment in each physical scenario, each economic scenario, each sector and each area.

5.2 FLOOD DAMAGE UNDER FUTURE SCENARIOS

Risk is a function of consequence and likelihood. In this report, risk, consequence and likelihood are defined as flood damage probability curve, damage curve and flood level frequency curve, respectively.

Flood Damage Probability Curve, Average Annual Damage (AAD) and Net Present Value (NPV) of AAD are illustrated under following scenarios in each area and each sector.

Table 14 Summary of Scenario in task 6

Scenario	**Year**				**USD&FPD (Loss of flood storage, %)**				**Climate Change**
	2014	2020	2040	2060	0	25	50	75	
Physical development									
BDS0-2014	O				O				
BDS1-2020		O				O			
BDS2-2040			O				O		
BDS3-2060				O				O	
BDS3cc-2060cc				O				O	O
Economic development									
Scenario 1(A1N1) Business as Usual		O	O	O					
Scenario 2 (A2N1) Greater value-added Rice		O	O	O					

5.2.1 MUANG CHIANG RAI (CR)

Flood Level Frequency Curve under the previous scenario in Muang Chiang Rai is shown as follow. It is certain that case of with climate change (BDS3cc-2060cc) causes greater annual maximum water level, comparing with case of without climate change (BDS3-2060).

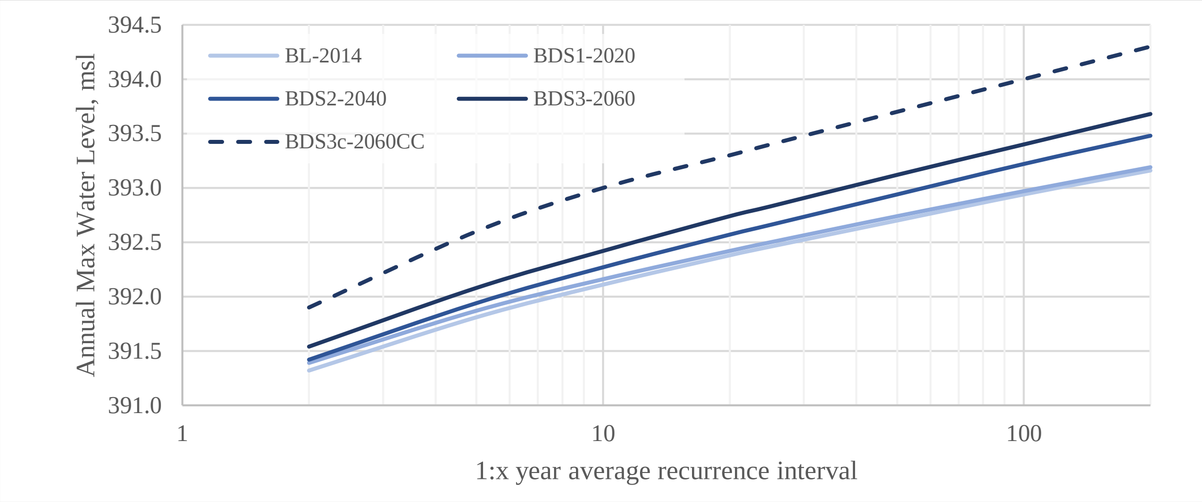

Figure 36 Flood Level Frequency Curve in Muang, Chiang Rai

5.2.1.1 CR: SCENARIO 1(A1N1) BUSINESS AS USUAL

Risk or flood damage probability curve in Muang, Chiang Rai in each economic sector (all, agriculture and non-agriculture) for scenario 1 (A1N1) "business as usual" is illustrated. Greater flood risk results from climate change.

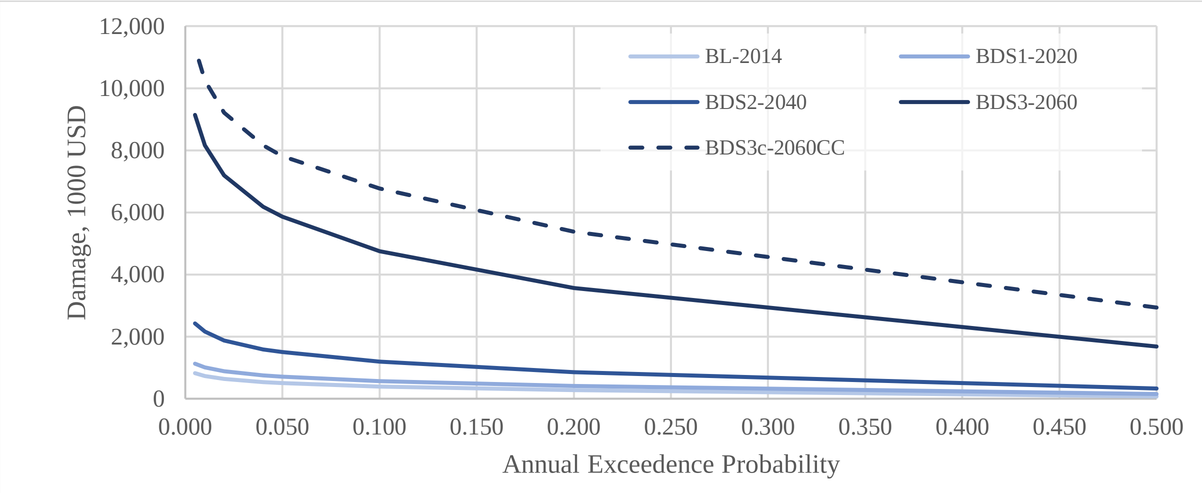

Figure 37 Flood Damage Probability Curve in Muang, Chiang Rai: all sector, (A1N1)

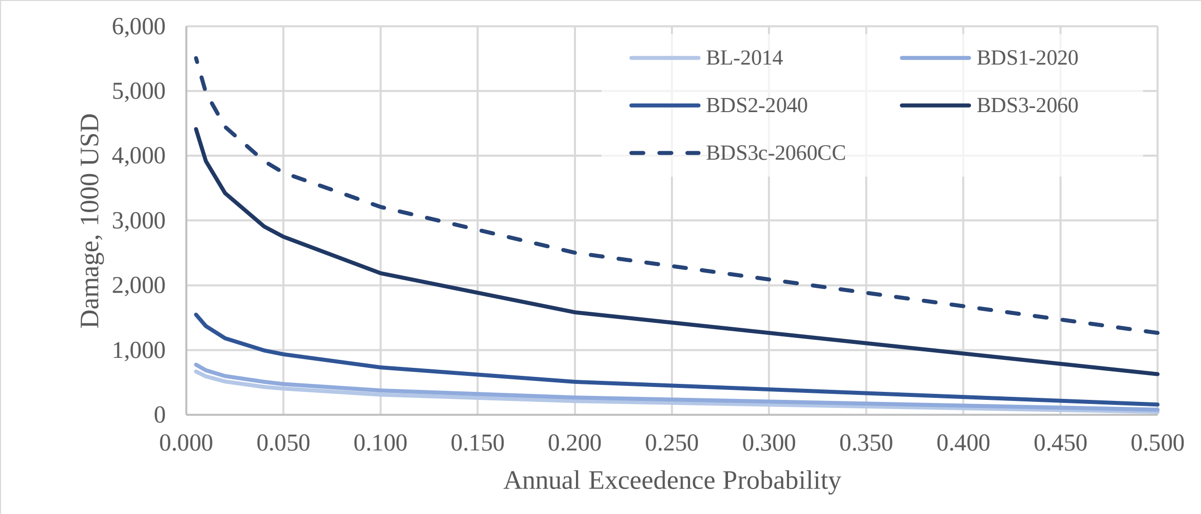

Figure 38 Flood Damage Probability Curve in Muang, Chiang Rai: agriculture, (A1N1)

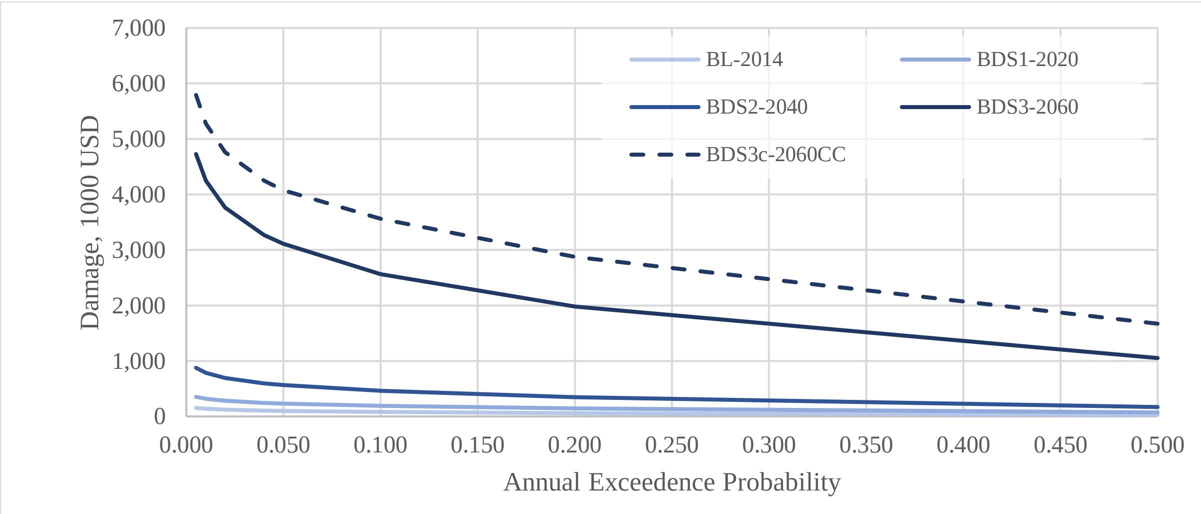

Figure 39 Flood Damage Probability Curve in Muang, Chiang Rai: non-agriculture, (A1N1)

5.2.1.2 CR: SCENARIO 2 (A2N1) GREATER VALUE-ADDED RICE

Risk or flood damage probability curve in Muang, Chiang Rai in each economic sector (all, agriculture and non-agriculture) for scenario 2 (A2N1) "greater value-added rice" is illustrated. Calculation results of flood risk in scenario 2 is greater than scenario 1. This caused by increasing economic value of organic rice.

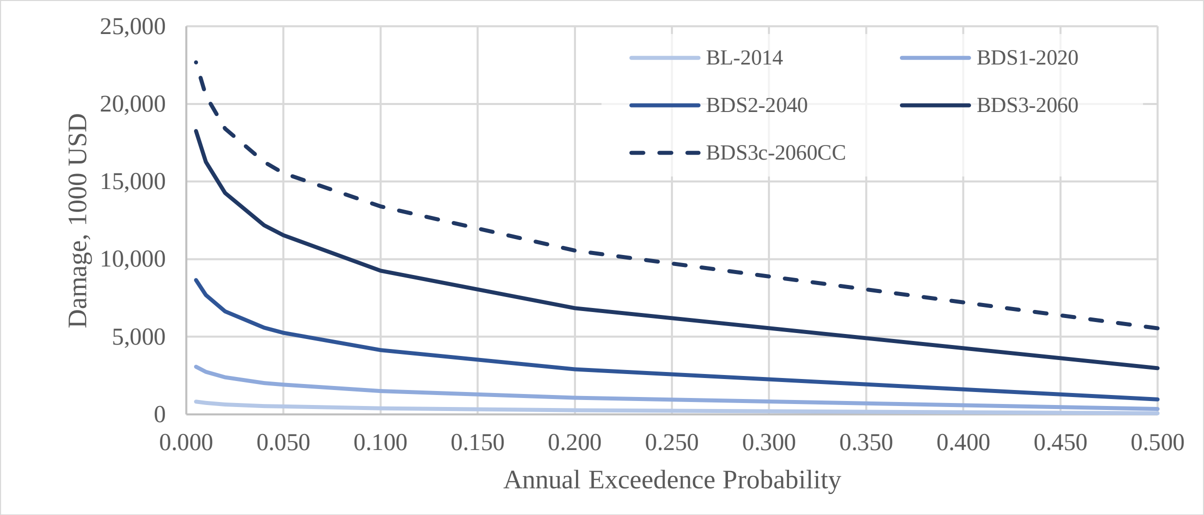

Figure 40 Flood Damage Probability Curve in Muang, Chiang Rai: all sector, (A2N1)

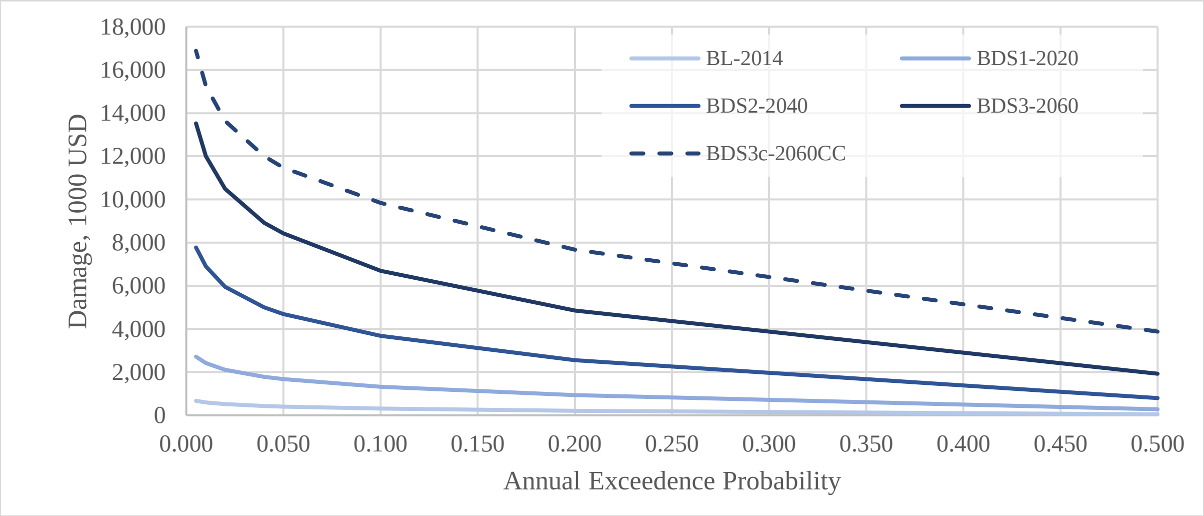

Figure 41 Flood Damage Probability Curve in Muang, Chiang Rai: agriculture, (A2N1)

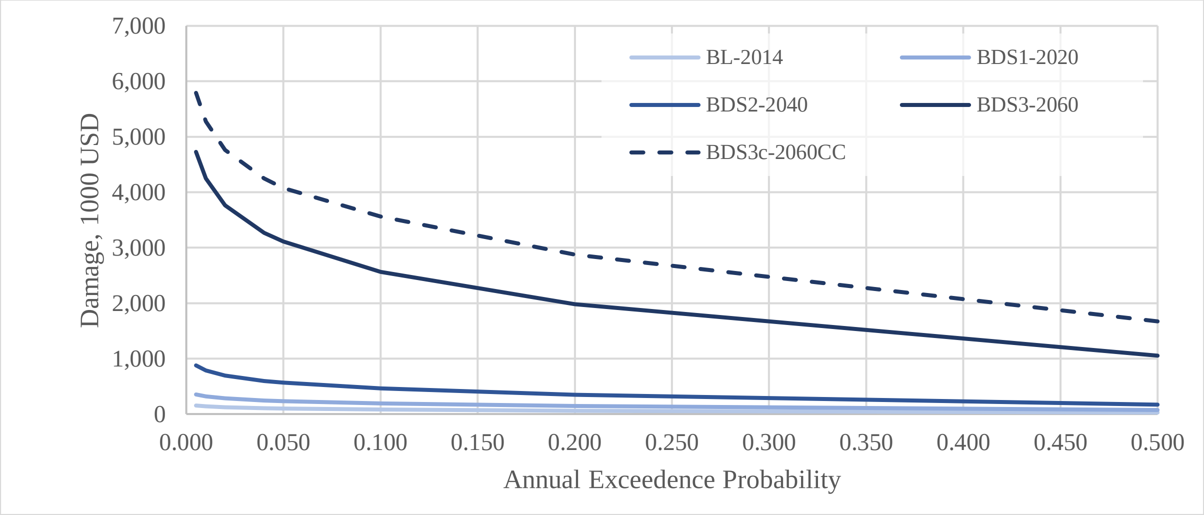

Figure 42 Flood Damage Probability Curve in Muang, Chiang Rai: non-agriculture, (A1N1)

5.2.2 MUANG CHIANG SAEN (CS)

Flood Level Frequency Curve under the previous scenario in Muang Chiang Saen is shown as follow. It is certain that case of with climate change (BDS3cc-2060cc) causes greater annual maximum water level, comparing with case of without climate change (BDS3-2060).

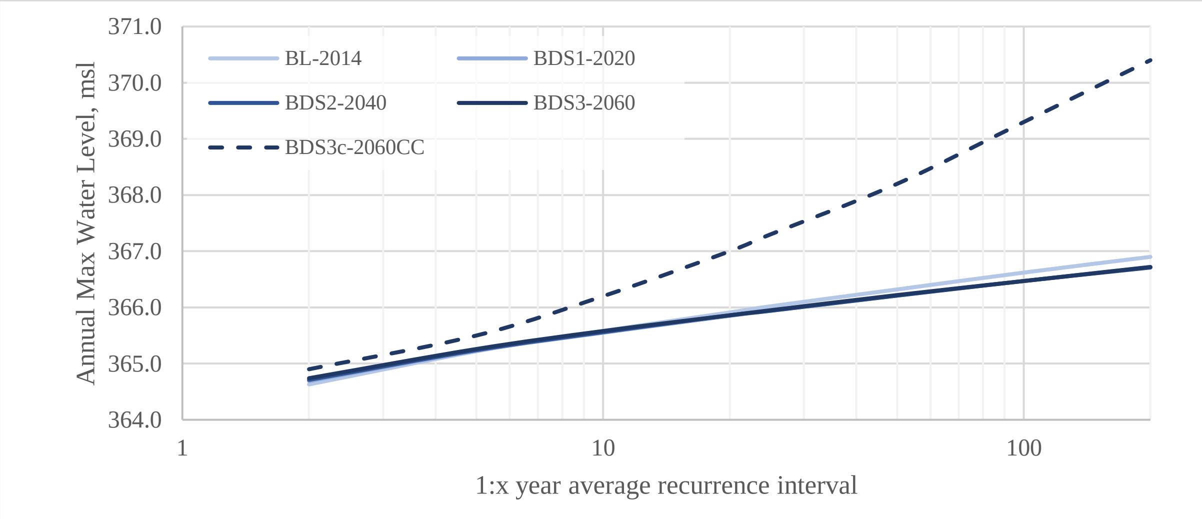

Figure 43 Flood Level Frequency Curve in Muang, Chiang Saen

5.2.2.1 CS: SCENARIO 1(A1N1) BUSINESS AS USUAL

Risk or flood damage probability curve in Muang, Chiang Saen in each economic sector (all, agriculture and non-agriculture) for scenario 1 (A1N1) "business as usual" is illustrated. Greater flood risk results from climate change.

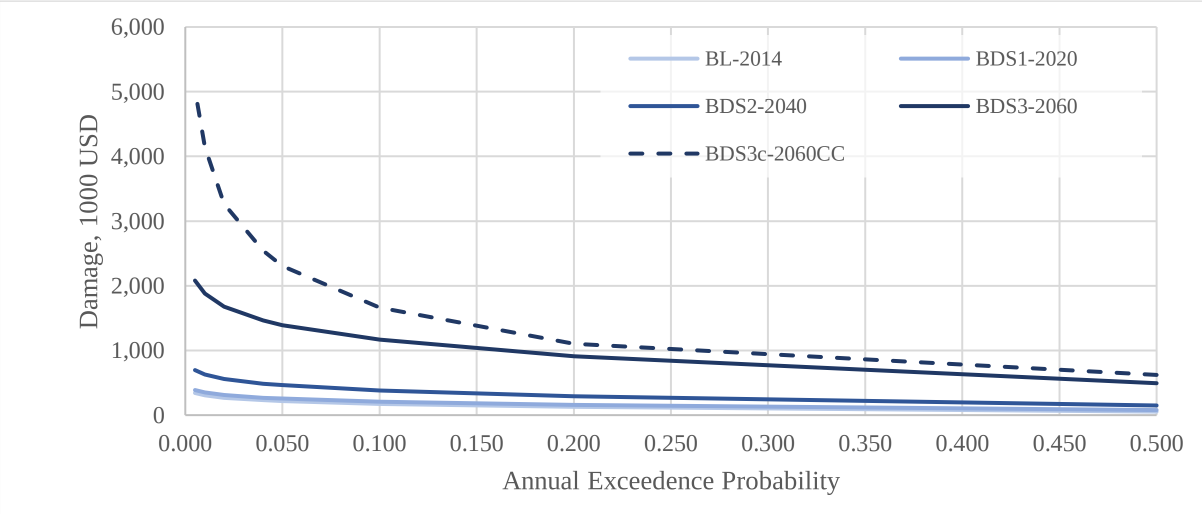

Figure 44 Flood Damage Probability Curve in Muang, Chiang Saen: all sector, (A1N1)

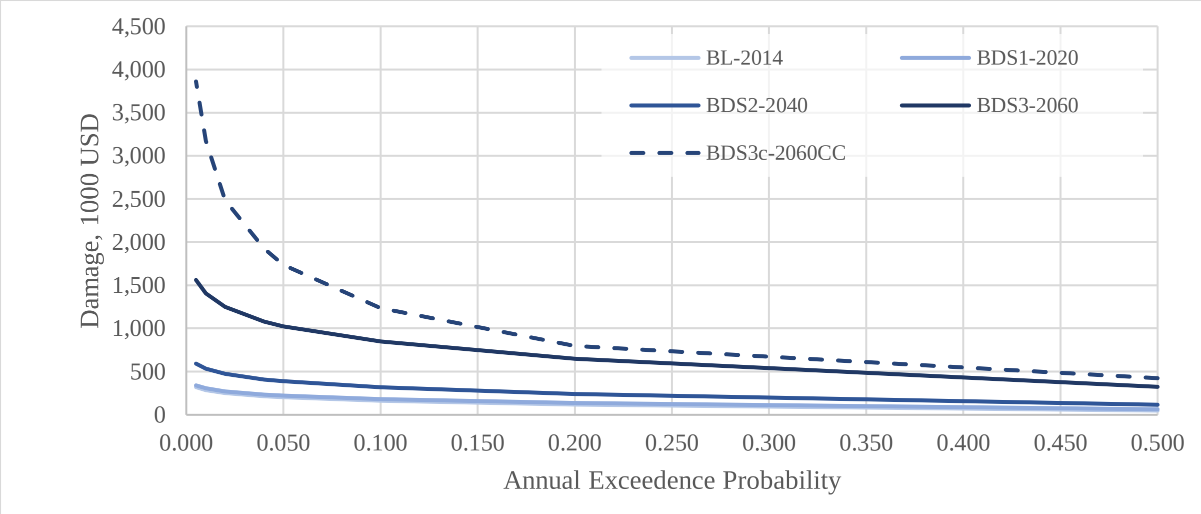

Figure 45 Flood Damage Probability Curve in Muang, Chiang Saen: agriculture, (A1N1)

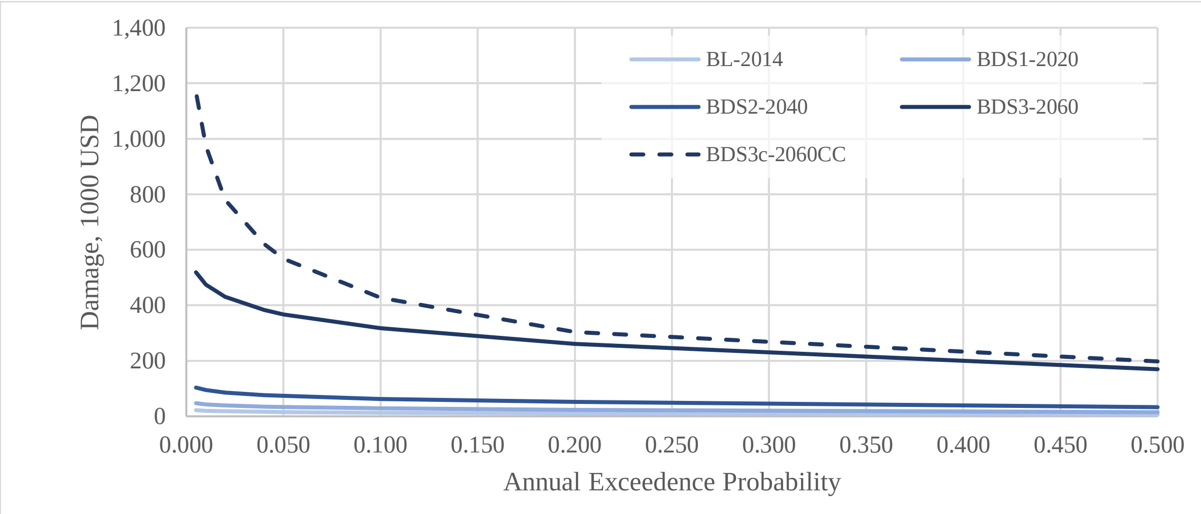

Figure 46 Flood Damage Probability Curve in Muang, Chiang Saen: non-agriculture, (A1N1)

5.2.2.2 CS: SCENARIO 2 (A2N1) GREATER VALUE-ADDED RICE

Risk or flood damage probability curve in Muang, Chiang Saen in each economic sector (all, agriculture and non-agriculture) for scenario 2 (A2N1) "greater value-added rice" is illustrated. Calculation results of flood risk in scenario 2 is greater than scenario 1. This caused by increasing economic value of organic rice.

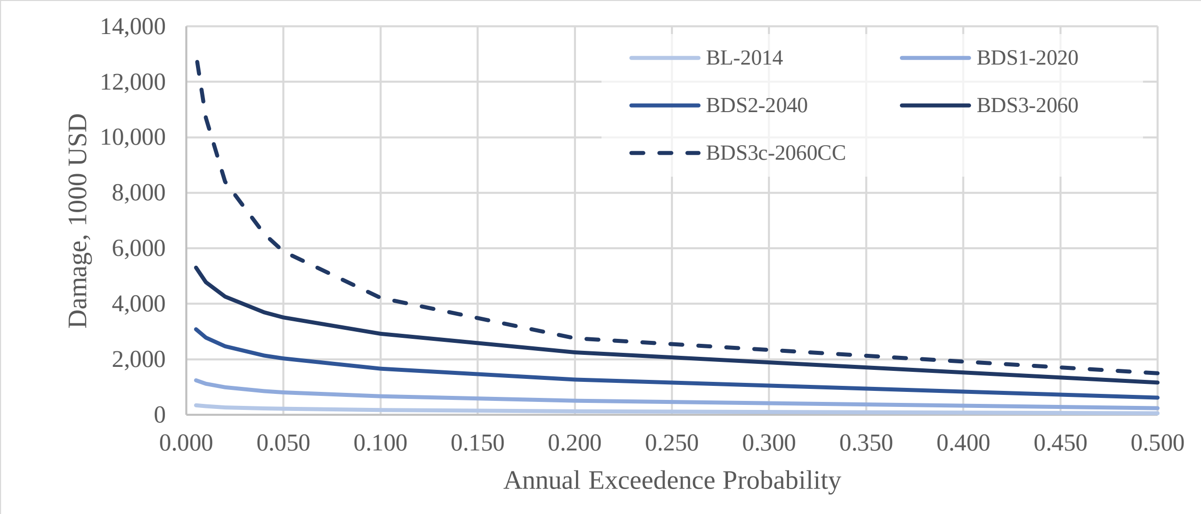

Figure 47 Flood Damage Probability Curve in Muang, Chiang Saen: all sector, (A2N1)

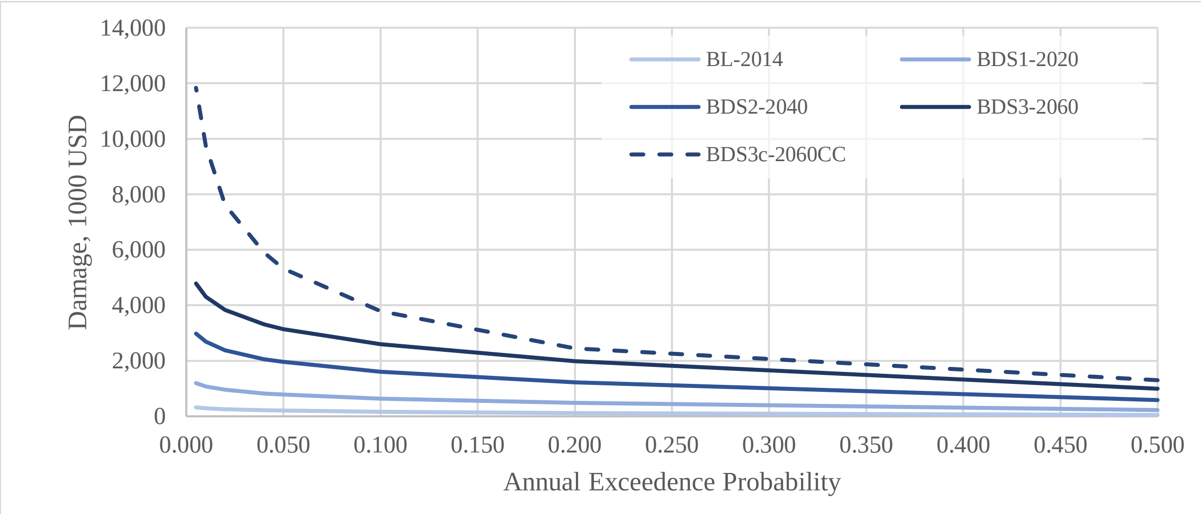

Figure 48 Flood Damage Probability Curve in Muang, Chiang Saen: agriculture, (A2N1)

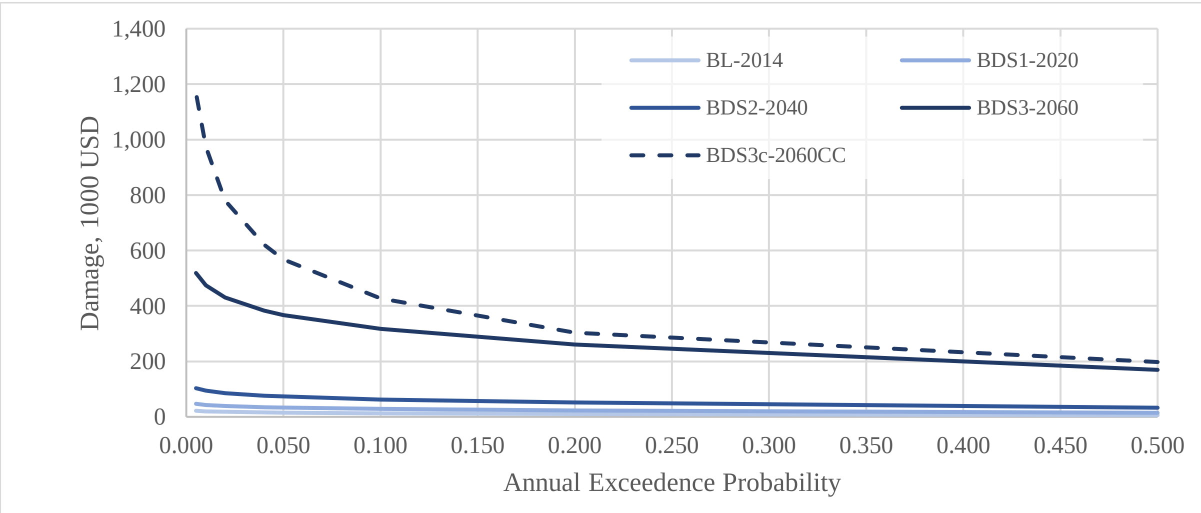

Figure 49 Flood Damage Probability Curve in Muang, Chiang Saen: non-agriculture, (A1N1)

5.3 AVERAGE ANNUAL DAMAGE UNDER FUTURE SCENARIOS

Risk assessment can be defined as **Average Annual Damage (AAD)** which is total annual risk or area under damage probability curve.

Net Present Value (NPV) of AAD is value of an average annual damage today after considering the time value of money.

Average annual damage (ADD) and net present value (NPV) of flood damage of A1N1 scenario in each sector, each scenario and each year are calculated and illustrated in following table.

Table 15 ADD and NPV of ADD of flood damage

Value	Sector	Annual Average Damage, ADD, 1000 USD				
		BL-2014	BDS1-2020	BDS2-2040	BDS3-2060	BDS3c-2060CC
Muang, Chiang Rai: scenario 1 (A1N1)						
Market price	Agriculture	107	133	259	804	1,234
	Non-Agriculture	30	73	174	989	1,404
	All sectors	135	204	429	1,781	2,623
Net present value	Agriculture	107	115	136	258	396
	Non-Agriculture	30	63	92	318	451
	All sectors	135	176	226	572	842
Muang, Chiang Rai: scenario 2 (A2N1)						
Market price	Agriculture	107	467	1,302	804	3,781
	Non-Agriculture	30	73	174	989	1,404
	All sectors	135	533	1,457	1,781	5,142
Net present value	Agriculture	107	403	685	258	1,214
	Non-Agriculture	30	63	92	318	451
	All sectors	135	459	767	572	1,651
Muang, Chiang Saen: scenario 1 (A1N1)						
Market price	Agriculture	60	69	122	326	477
	Non-Agriculture	5	12	26	130	171
	All sectors	65	80	146	452	639
Net present value	Agriculture	60	59	64	105	153
	Non-Agriculture	5	10	13	42	55
	All sectors	65	69	77	145	205
Muang, Chiang Saen: scenario 2 (A2N1)						
Market price	Agriculture	60	242	612	999	1,464
	Non-Agriculture	5	12	26	130	171
	All sectors	65	251	630	1,117	1,605
Net present value	Agriculture	60	209	322	321	470
	Non-Agriculture	5	10	13	42	55
	All sectors	65	216	332	359	515

5.4 CONCLUSION

Calculation of flood damage probability or flood risk and ADD of Muang, Chiang Rai and Chiang Saen in each physical scenario, each economic scenario and each sector has been successful. Climate change seem to be majority of flood damage, especially in the far future (year 2060). The next issue is how to reduce these flood risks which is shown in task 7 (next chapter).

CHAPTER 6

STRATEGIC DIRECTIONS FOR FLOOD RISK MANAGEMENT (TASK 7)

6.1 INTRODUCTION

In this chapter, task 7 of the initial studies project is concentrated. Flood damage under future scenarios of proposed mitigation measure arr calculated and presented as Flood Damage Probability Curve. Average Annual Damage (AAD) and Net Present Value (NPV) of AAD are also illustrated for risk assessment in each physical scenario, each economic scenario, each sector and each area.

6.2 PROPOSED MITIGATION MEASURE

The flood risk due to Upstream Development (USD), Floodplain Development (FPD) with new flood structure with and without Climate Change is analyzed at representative location. The flood damage is calculated from flood behavior change.

The comparison was made based on scenarios composed of

- BDS3-Year 2060 (**BDS3-2060**)

When Including New Structure

- BDS3a-Year 2060 with Floodway in Nam Korn – Nam Lao (**BDS3a-2060Flw**) that effect of floodway mostly in Nam Korn-Nam Lao Floodplain
- BDS3b-Year 2060 with Bank Protection in Lower Nam Kok (**BDS3b-2060Bnk**) that effect of floodway mostly in Lower Nam Kok.

When Including New Structure and Climate Change

- BDS3c-Year 2060 with Climate change (**BDS3c-2060CC**)
- BDS3d-Year 2060 with Floodway in Nam Korn – Nam Lao and Climate change (**BDS3d-2060CCFlw**)
- BDS3e-Year 2060 with Bank Protection in Lower Nam Kok and Climate change (**BDS3e-2060CCBnk**)

Table 16 Summary of Scenario in Task 7

Scenario	Year				USD&FPD (Loss of flood storage, %)				Climate Change	New proposed structure	
	2014	2020	2040	2060	0	25	50	75		Flw	Bnk
BDS0-2014	O				O						
BDS1-2020		O				O					
BDS2-2040			O				O				
BDS3-2060				O				O			
BDS3cc-2060cc				O				O	O		
BDS3a-2060Flw				O				O		O	
BDS3b-2060Bnk				O				O			O
BDS3d-2060CCFlw				O				O	O	O	
BDS3e-2060CCBnk				O				O	O		O

6.2.1 MUANG CHIANG RAI (CR)

Flood Level Frequency Curve under the previous scenario in Muang Chiang Rai is shown as follow. It is certain that case of with climate change (BDS3cc-2060cc) causes greater annual maximum water level, comparing with case of without climate change (BDS3-2060).

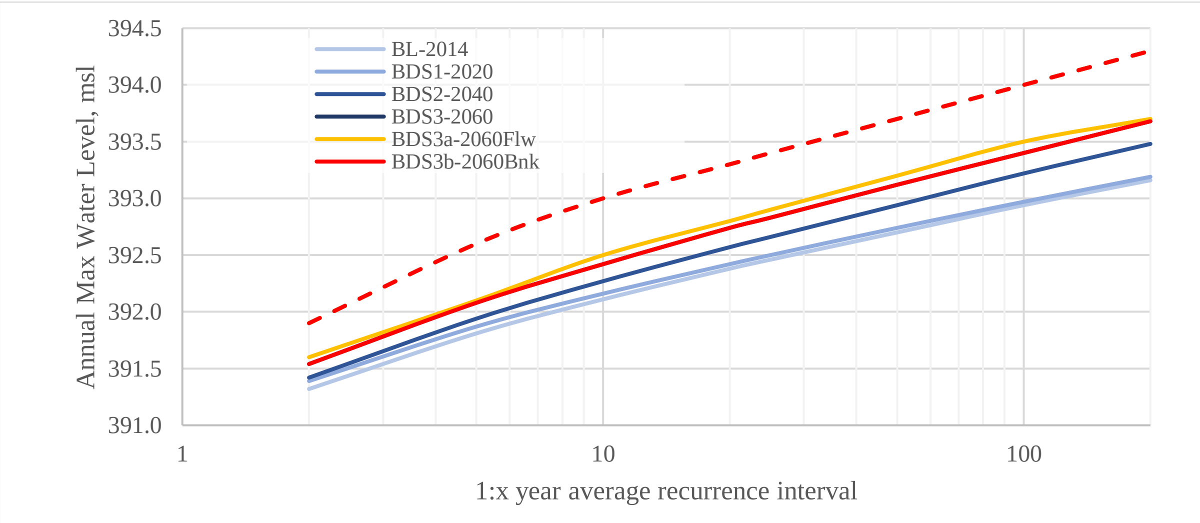

Figure 50 Flood Level Frequency Curve in Muang, Chiang Rai

6.2.1.1 CR: SCENARIO 1(A1N1) BUSINESS AS USUAL

Risk or flood damage probability curve in Muang, Chiang Rai in each economic sector (all, agriculture and non-agriculture) for scenario 1 (A1N1) “business as usual” is illustrated. Greater flood risk results from climate change.

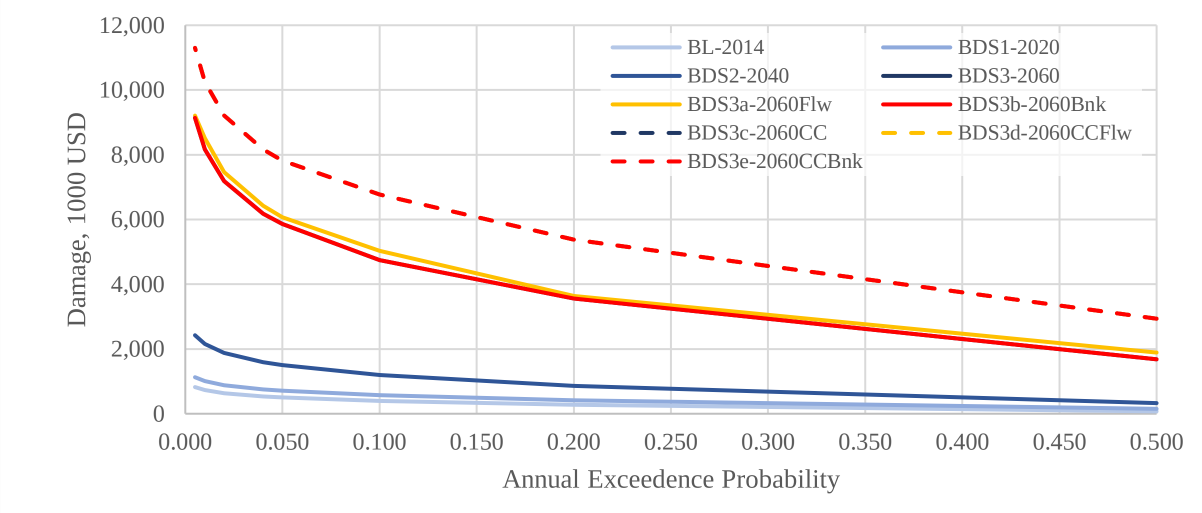

Figure 51 Flood Damage Probability Curve in Muang, Chiang Rai: all sector, (A1N1)

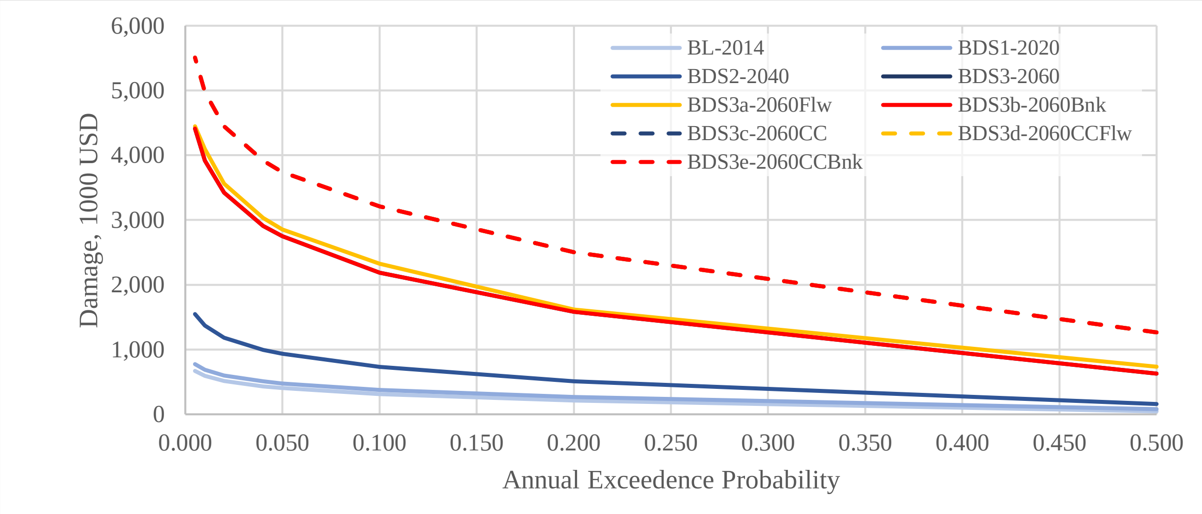

Figure 52 Flood Damage Probability Curve in Muang, Chiang Rai: agriculture, (A1N1)

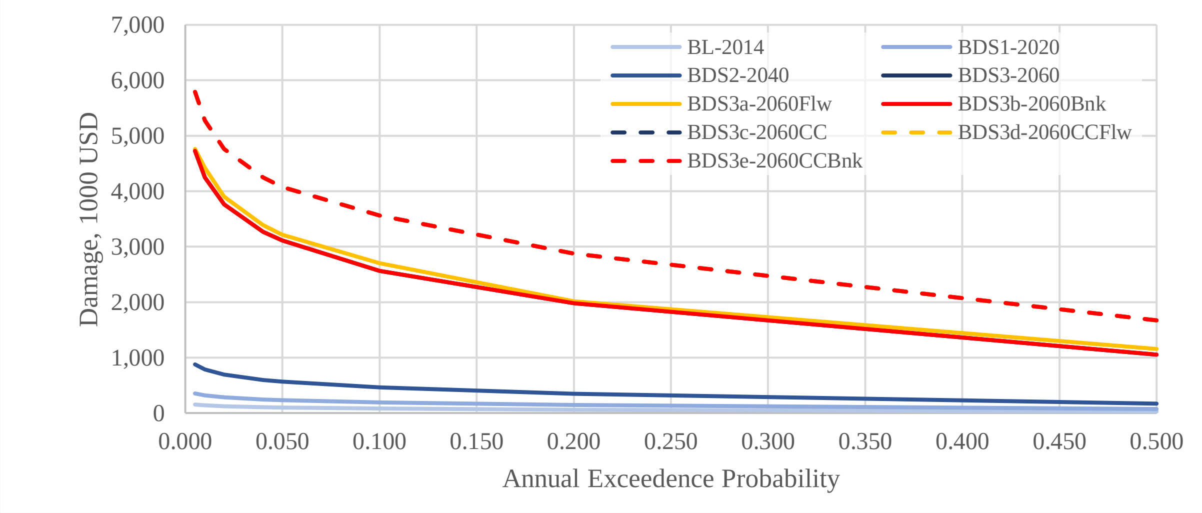

Figure 53 Flood Damage Probability Curve in Muang, Chiang Rai: non-agriculture, (A1N1)

6.2.1.2 CR: SCENARIO 2 (A2N1) GREATER VALUE-ADDED RICE

Risk or flood damage probability curve in Muang, Chiang Rai in each economic sector (all, agriculture and non-agriculture) for scenario 2 (A2N1) "greater value-added rice" is illustrated. Calculation results of flood risk in scenario 2 is greater than scenario 1. This caused by increasing economic value of organic rice.

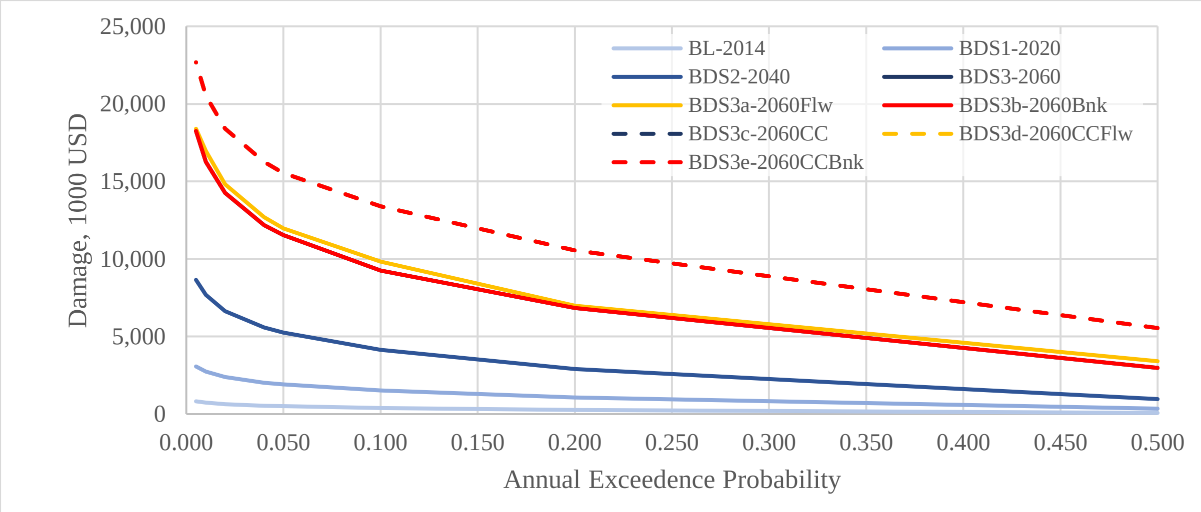

Figure 54 Flood Damage Probability Curve in Muang, Chiang Rai: all sector, (A2N1)

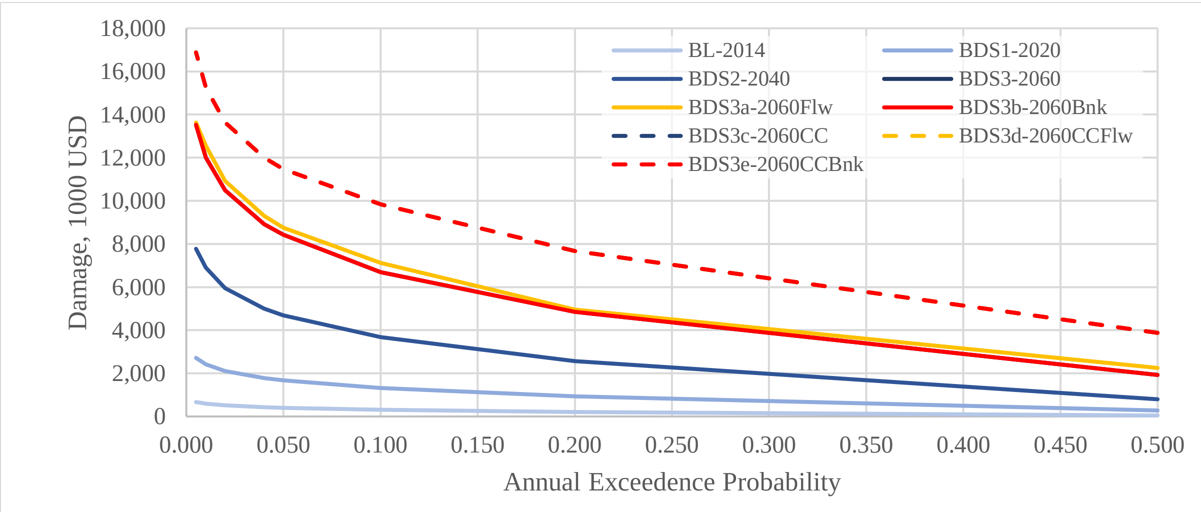

Figure 55 Flood Damage Probability Curve in Muang, Chiang Rai: agriculture, (A2N1)

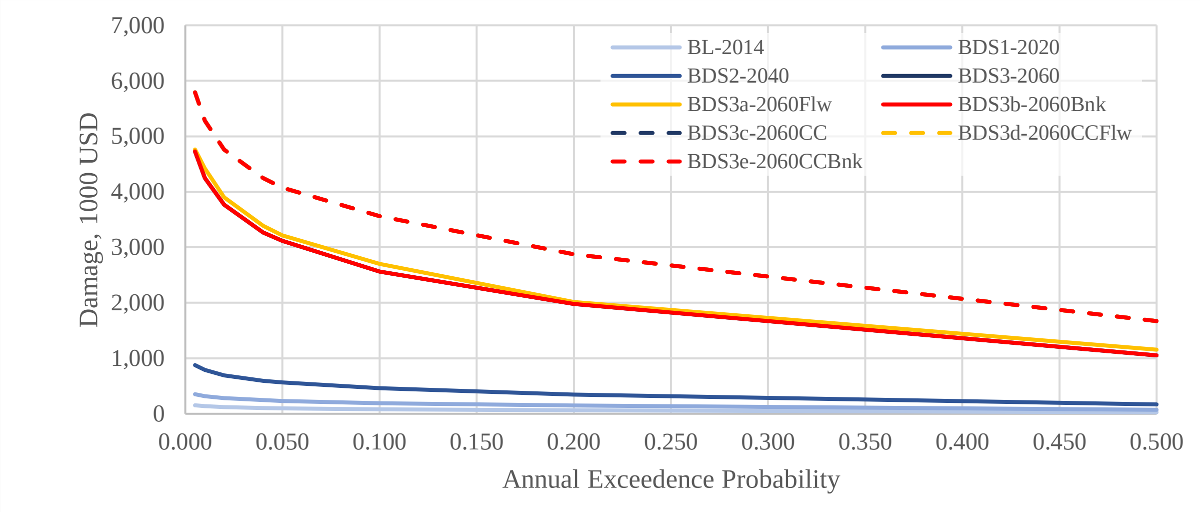

Figure 56 Flood Damage Probability Curve in Muang, Chiang Rai: non-agriculture, (A1N1)

6.2.1.3 DISCUSSIONS ON MUANG CHIANG RAI (CR)

The comparison was made based on following scenarios:

	Without Climate change	With Climate change
Without New Structure	**BDS3-2060**	**BDS3c-2060CC**
With New Structure	**BDS3a-2060Flw,** **BDS3b-2060Bnk**	**BDS3d-2060CCFlw** **BDS3e-2060CCBnk**

Note:

- BDS3-Year 2060 (**BDS3-2060**)

When Including New Structure

- BDS3a-Year 2060 with Floodway in Nam Korn – Nam Lao (**BDS3a-2060Flw**) that effect of floodway mostly in Nam Korn-Nam Lao Floodplain
- BDS3b-Year 2060 with Bank Protection in Lower Nam Kok (**BDS3b-2060Bnk**) that effect of floodway mostly in Lower Nam Kok.

When Including New Structure and Climate Change

- BDS3c-Year 2060 with Climate change (**BDS3c-2060CC**)
- BDS3d-Year 2060 with Floodway in Nam Korn – Nam Lao and Climate change (**BDS3d-2060CCFlw**)
- BDS3e-Year 2060 with Bank Protection in Lower Nam Kok and Climate change (**BDS3e-2060CCBnk**)

For case of MUANG CHIANG RAI (CR), The calculation results show that impact of floodway to flood risk is small compared to the greater risks from economic development and climate change. After discussion with expert team, the reason is that there are a set of existing flood-mitigation system to protect this area. This causes a small portion of reducing flood risk in Nam Korn-Nam Lao Floodplain, resulting from Floodway. In Bank Protection, it affects floodway mostly in Lower Nam Kok.

However, it is almost certain that climate change provides the high impact in this area. Climate change should be addressed by not only mitigation measures, but also adaptation measures such as strengthening coping capacity, increasing citizen awareness, providing early warning system, monitoring flood data and the other options.

6.2.2 MUANG CHIANG SAEN (CS)

Flood Level Frequency Curve under the previous scenario in Muang Chiang Saen is shown as follow. It is certain that case of with climate change (BDS3cc-2060cc) causes greater annual maximum water level, comparing with case of without climate change (BDS3-2060).

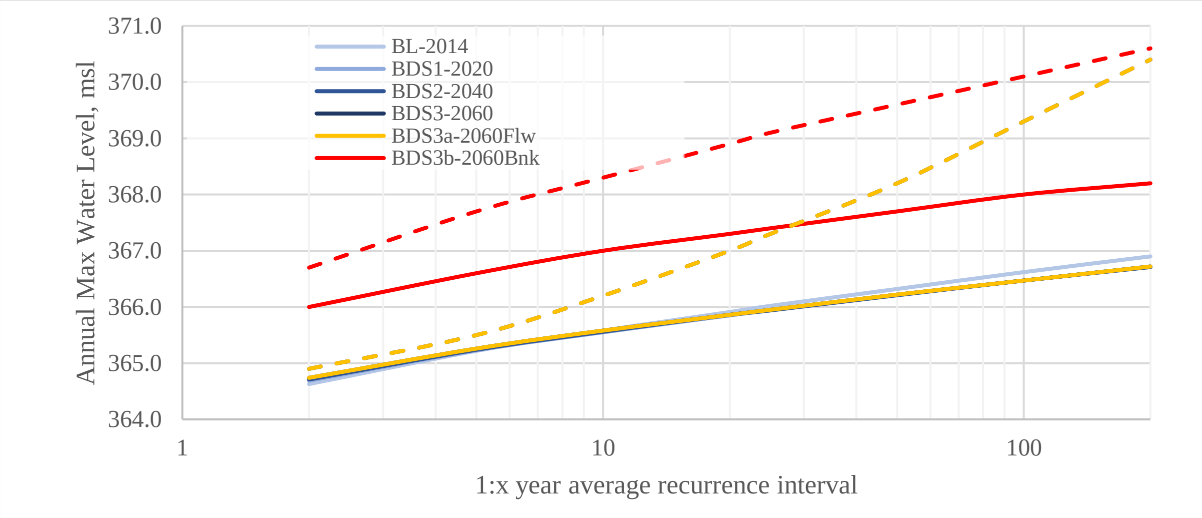

Figure 57 Flood Level Frequency Curve in Muang, Chiang Saen

6.2.2.1 CS: SCENARIO 1(A1N1) BUSINESS AS USUAL

Risk or flood damage probability curve in Muang, Chiang Saen in each economic sector (all, agriculture and non-agriculture) for scenario 1 (A1N1) "business as usual" is illustrated. Greater flood risk results from climate change.

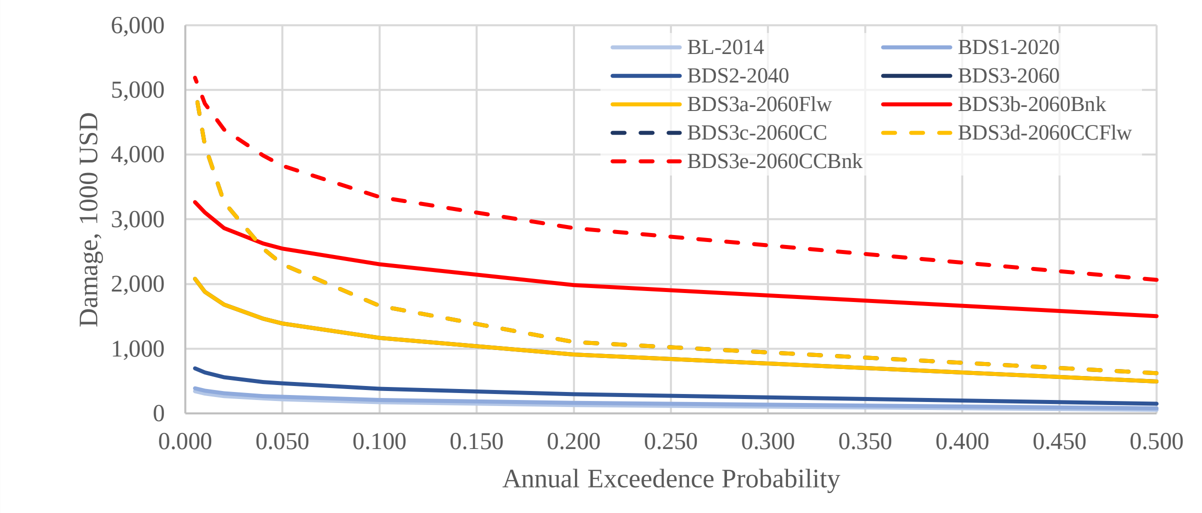

Figure 58 Flood Damage Probability Curve in Muang, Chiang Saen: all sector, (A1N1)

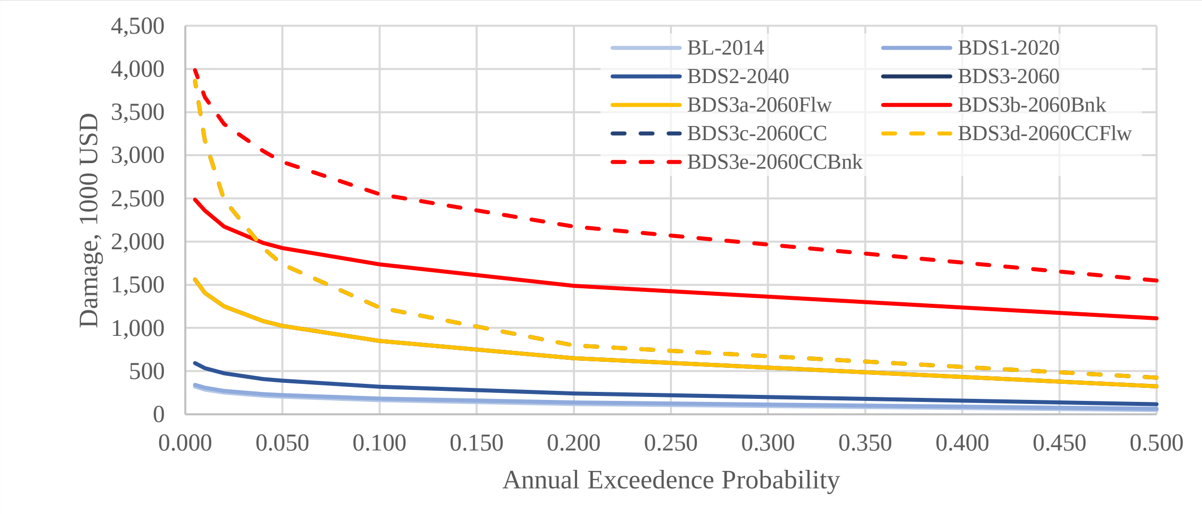

Figure 59 Flood Damage Probability Curve in Muang, Chiang Saen: agriculture, (A1N1)

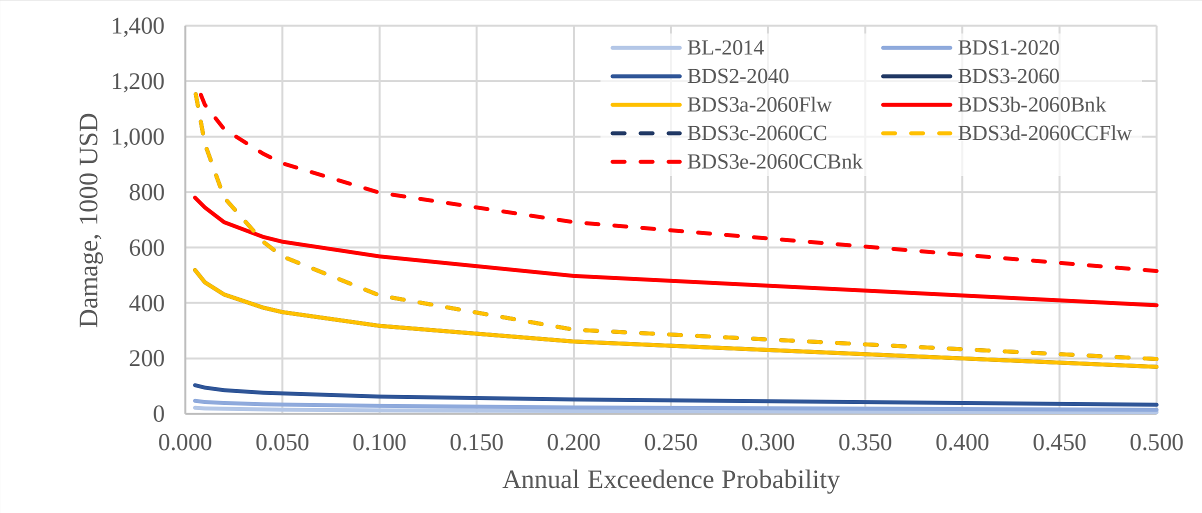

Figure 60 Flood Damage Probability Curve in Muang, Chiang Saen: non-agriculture, (A1N1)

6.2.2.2 CS: SCENARIO 2 (A2N1) GREATER VALUE-ADDED RICE

Risk or flood damage probability curve in Muang, Chiang Saen in each economic sector (all, agriculture and non-agriculture) for scenario 2 (A2N1) "greater value-added rice" is illustrated. Calculation results of flood risk in scenario 2 is greater than scenario 1. This caused by increasing economic value of organic rice.

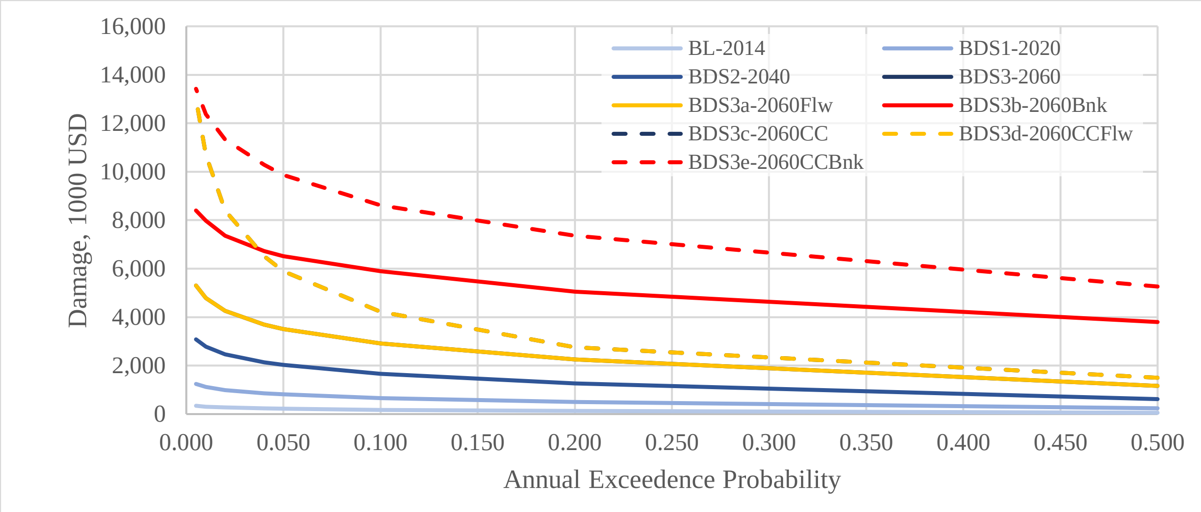

Figure 61 Flood Damage Probability Curve in Muang, Chiang Saen: all sector, (A2N1)

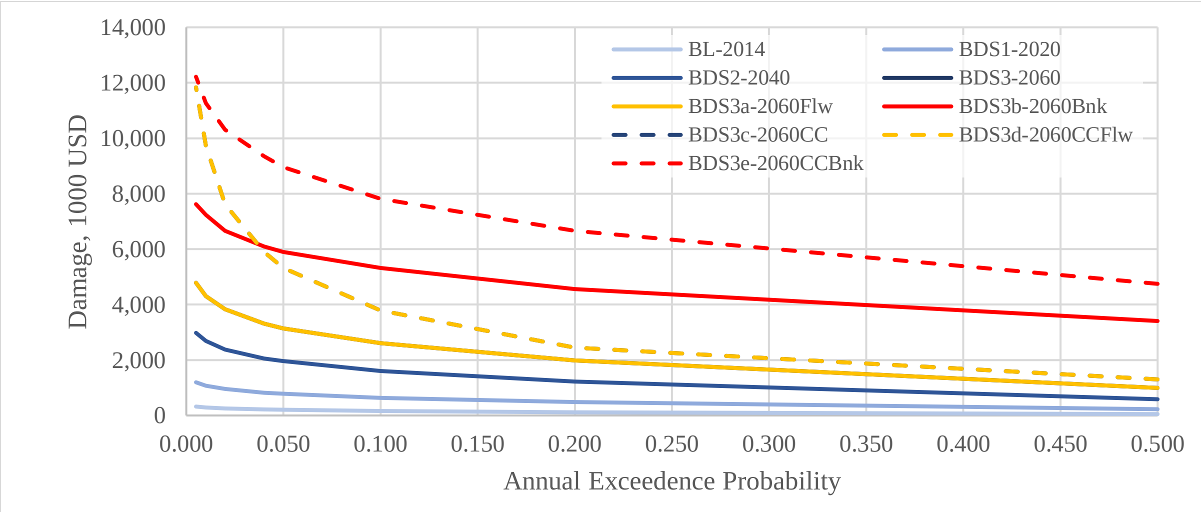

Figure 62 Flood Damage Probability Curve in Muang, Chiang Saen: agriculture, (A2N1)

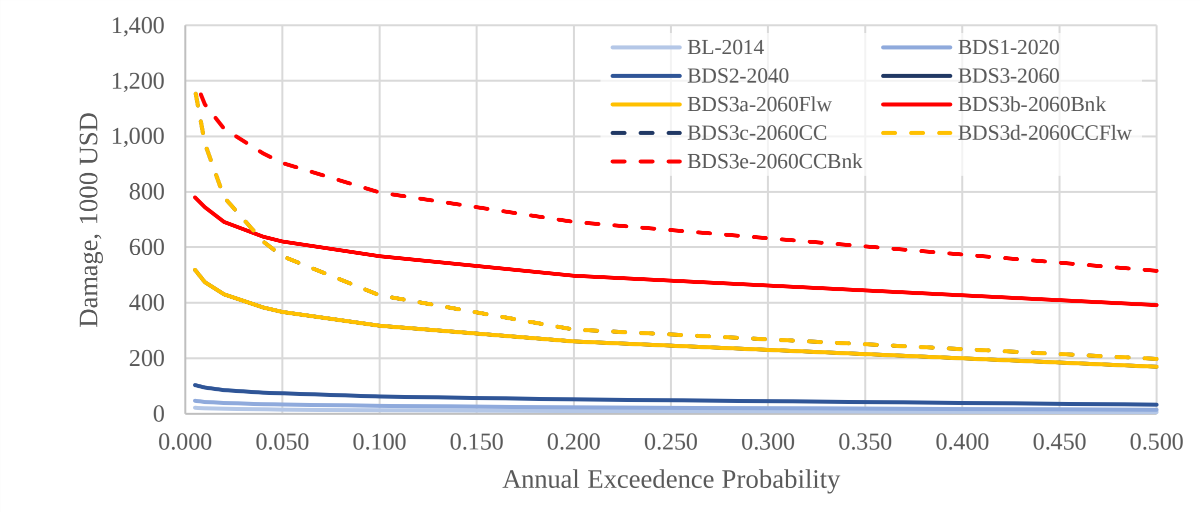

Figure 63 Flood Damage Probability Curve in Muang, Chiang Saen: non-agriculture, (A1N1)

6.2.2.3 DISCUSSIONS ON MUANG, CHIANG SAEN (CS)

The comparison was made based on following scenarios:

	Without Climate change	With Climate change
Without New Structure	**BDS3-2060**	**BDS3c-2060CC**
With New Structure	**BDS3a-2060Flw, BDS3b-2060Bnk**	**BDS3d-2060CCFlw BDS3e-2060CCBnk**

Note:

- BDS3-Year 2060 (**BDS3-2060**)

When Including New Structure

- BDS3a-Year 2060 with Floodway in Nam Korn – Nam Lao (**BDS3a-2060Flw**) that effect of floodway mostly in Nam Korn-Nam Lao Floodplain
- BDS3b-Year 2060 with Bank Protection in Lower Nam Kok (**BDS3b-2060Bnk**) that effect of floodway mostly in Lower Nam Kok.

When Including New Structure and Climate Change

- BDS3c-Year 2060 with Climate change (**BDS3c-2060CC**)
- BDS3d-Year 2060 with Floodway in Nam Korn – Nam Lao and Climate change (**BDS3d-2060CCFlw**)
- BDS3e-Year 2060 with Bank Protection in Lower Nam Kok and Climate change (**BDS3e-2060CCBnk**)

For case of MUANG CHIANG SAEN (CS), The calculation results show that impact of bank protection to flood risk is small compared to the greater risks from economic development and climate change. After discussion with expert team, it results from the backwater effect from Mekong River. Bank protection measure may also cause the higher water level in downstream. For floodway measure, it affects mostly in Nam Korn – Nam Lao.

However, it is almost certain that climate change provides the high impact in this area. Climate change should be addressed by not only mitigation measures, but also adaptation measures such as strengthening coping capacity, increasing citizen awareness, providing early warning system, monitoring flood data and the other options.

6.3 AVERAGE ANNUAL DAMAGE UNDER FUTURE SCENARIOS

Risk assessment can be defined as **Average Annual Damage (AAD)** which is total annual risk or area under damage probability curve.

Net Present Value (NPV) of AAD is value of an average annual damage today after considering the time value of money.

Average annual damage (ADD) and net present value (NPV) of flood damage of A1N1 scenario in each sector, each scenario and each year are calculated and illustrated in following table

Table ADD and NPV of ADD of flood damage

Value	Sector	Annual Average Damage, ADD, 1000 USD					
		BDS3-2060	BDS3a-2060 Flw	BDS3b-2060 Bnk	BDS3c-2060CC	BDS3d-2060CC Flw	BDS3e-2060CC Bnk
Muang, Chiang Rai: scenario 1 (A1N1)							
Market price	Agriculture	804	846	804	1,234	1,234	1,234
	Non-Agriculture	989	1,030	989	1,404	1,404	1,404
	All sectors	1,781	1,864	1,781	2,623	2,623	2,623
Net present value	Agriculture	258	272	258	396	396	396
	Non-Agriculture	318	331	318	451	451	451
	All sectors	572	599	572	842	842	842
Muang, Chiang Rai: scenario 2 (A2N1)							
Market price	Agriculture	2,463	2,593	2,463	3,781	3,781	3,781
	Non-Agriculture	989	1,030	989	1,404	1,404	1,404
	All sectors	3,418	3,588	3,418	5,142	5,142	5,142
Net present value	Agriculture	791	833	791	1,214	1,214	1,214
	Non-Agriculture	318	331	318	451	451	451
	All sectors	1,098	1,152	1,098	1,651	1,651	1,651
Muang, Chiang Saen: scenario 1 (A1N1)							
Market price	Agriculture	326	326	744	477	477	1,090
	Non-Agriculture	130	130	247	171	171	343
	All sectors	452	452	985	639	639	1,423
Net present value	Agriculture	105	105	239	153	153	350
	Non-Agriculture	42	42	79	55	55	110
	All sectors	145	145	316	205	205	457
Muang, Chiang Saen: scenario 2 (A2N1)							
Market price	Agriculture	999	999	2,282	1,464	1,464	3,340
	Non-Agriculture	130	130	247	171	171	343
	All sectors	1,117	1,117	2,510	1,605	1,605	3,652
Net present value	Agriculture	321	321	733	470	470	1,073
	Non-Agriculture	42	42	79	55	55	110
	All sectors	359	359	806	515	515	1,173

6.4 CONCLUSION

Calculation of flood damage probability or flood risk and ADD of Muang, Chiang Rai and Chiang Saen in each physical scenario, each economic scenario and each sector including proposed new infrastructures has been successful. The impact of water-infrastructure is small compared to climate change. This causes by exiting flood mitigation system, backwater effect from Mekong River and locations. Climate change seem to be majority of flood damage, especially in the far future (year 2060). Policy makers should carefully consider how to address the future flood risk in both structural measures and non-structural options.

CHAPTER 7

CONCLUSION AND RECOMMENDATION

7.1 CONCLUSION

We have successfully provided technical inputs, assess and formulate issues for Nam Mae Kok basin floodplain in Thailand to implement the Tasks of Initial Studies Stage-2.

Possible future flood behavior under conditions of inferred future climate change, future upstream developments (dams) and future floodplain development is assessed by scenario-based approach. The set of scenarios is considered with a number of issues including (1) upstream dam development in China (USD), (2) floodplain development resulting in loss of flood storage (FPD), (3) climate change and (4) new proposed structure in each area (Muang, Chiang Rai and Chiang Saen) and each year (2014, 2020, 2040, 2060).

Scenario	**Year**				**USD&FPD (Loss of flood storage, %)**				**Climate Change**	**New proposed structure**	
	2014	2020	2040	2060	0	25	50	75		Flw	Bnk
BDS0-2014	O				O						
BDS1-2020		O				O					
BDS2-2040			O				O				
BDS3-2060				O				O			
BDS3cc-2060cc				O				O	O		
BDS3a-2060Flw				O				O		O	
BDS3b-2060Bnk				O				O			O
BDS3d-2060CCFlw				O				O	O	O	
BDS3e-2060CCBnk				O				O	O		O

Flood damage curve and flood damage probability curve are calculated to illustrate existing and future flood damage estimation relationships in each developed scenario.

Existing and future flood event damage and average annual damage are also developed by using Average Annual Damage (AAD) and Net Present Value (NPV) of AAD for risk assessment in each physical scenario, each economic scenario, each sector and each area.

Pilot studies of new proposed structure are demonstrated the formulation of strategic directions to manage existing, future and residual flood risks in this area. Calculation results show that climate change provides greater flood risk and damage in the future. The impact of water-infrastructure is small compared to climate change. This causes by exiting flood mitigation system, backwater effect from Mekong River and locations. Climate change seem to be majority of flood damage, especially in the far future (year 2060).

7.2 RECOMMENDATION

- Policy makers should carefully consider how to address the future flood risk in both structural measures and non-structural options.
- Citizen participation in flood risk reduction should be considered.
- Information and technology should be shared among all related local agencies in flood prevention and mitigation in regional and local levels.
- Capacity building to the planning and operational staffs to flood should be strengthened. In addition, encouragement of persons in charge of monitoring and communication is recommended.
- Communication between line agency and local people should be carefully considered and developed.
- Legal and institutional arrangement for flood risk reduction should be transformed for local community to easily implement.

REFERENCES

Kittipong Jirayoot (2009), 1D ISIS Model Set-up and Flood Mapping for Kok River Basin, Mekong River Commission.

MRC (2005), Overview of the hydrology of the Mekong Basin, Mekong River Comission. *Mekong River Commission (MRC)*, November 2005.

MRC (2010), Impacts of climate change and the development on Mekong flow regimes – First assessment 2009 (MRC Technical Paper No. 29). *Mekong River Commission (MRC)*, June 2010.

MRC (2011), Assessment of Basin-wide development scenarios (Main Report for the Basin Development Plan Programme, Phase 2). *Mekong River Commission (MRC)*, April 2011.

MRC (2004), Decision Support Framework: Main Report, Water Utilization Programme, Mekong River Commission.

MRC (2010), Impacts of climate change and development on Mekong flow regimes: First assessment – 2009, Technical Paper No.29, Mekong River Commission.

MRC (2011a), Assessment of basin-wide development scenarios, Basin Development Plan Programme Phase 2, Mekong River Commission.

MRC (2011b), IWRM-Based Development Strategy 2011-2015 for Lower Mekong Basin, Basin Development Plan Programme Phase2, Mekong River Commission.

MRC (2014), Council Study: Inception Report, Mekong River Commission.

IKMP (2009). Final Report: Detailed Modelling Support Project (DMS), Information and Knowledge Management Programme, Mekong River Commission.

IKMP (2013), Technical report (Draft), climatic and hydrological data for model applications in Mekong River Basin, Information and Knowledge Management Programme, Mekong River Commission.

IKMP (2014a), Technical Reference Report (Draft), SWAT Model (Baseline 2007) Application in Mekong River Basin, Information and Knowledge Management Programme, Mekong River Commission.

IKMP (2014b), Technical Reference Report (Draft), IQQM Model (Baseline 2007) Application in Mekong River Basin, Information and Knowledge Management Programme, Mekong River Commission.

IKMP (2014c), Final Technical Report, Improvement of the ISIS Baseline Scenario Model, Information and Knowledge Management Programme, Mekong River Commission.

IKMP (2014d), Final Technical Report, the ISIS Baseline Model for Mekong River in Upper Kratie (Chiang Sean-Pakse), Information and Knowledge Management Programme, Mekong River