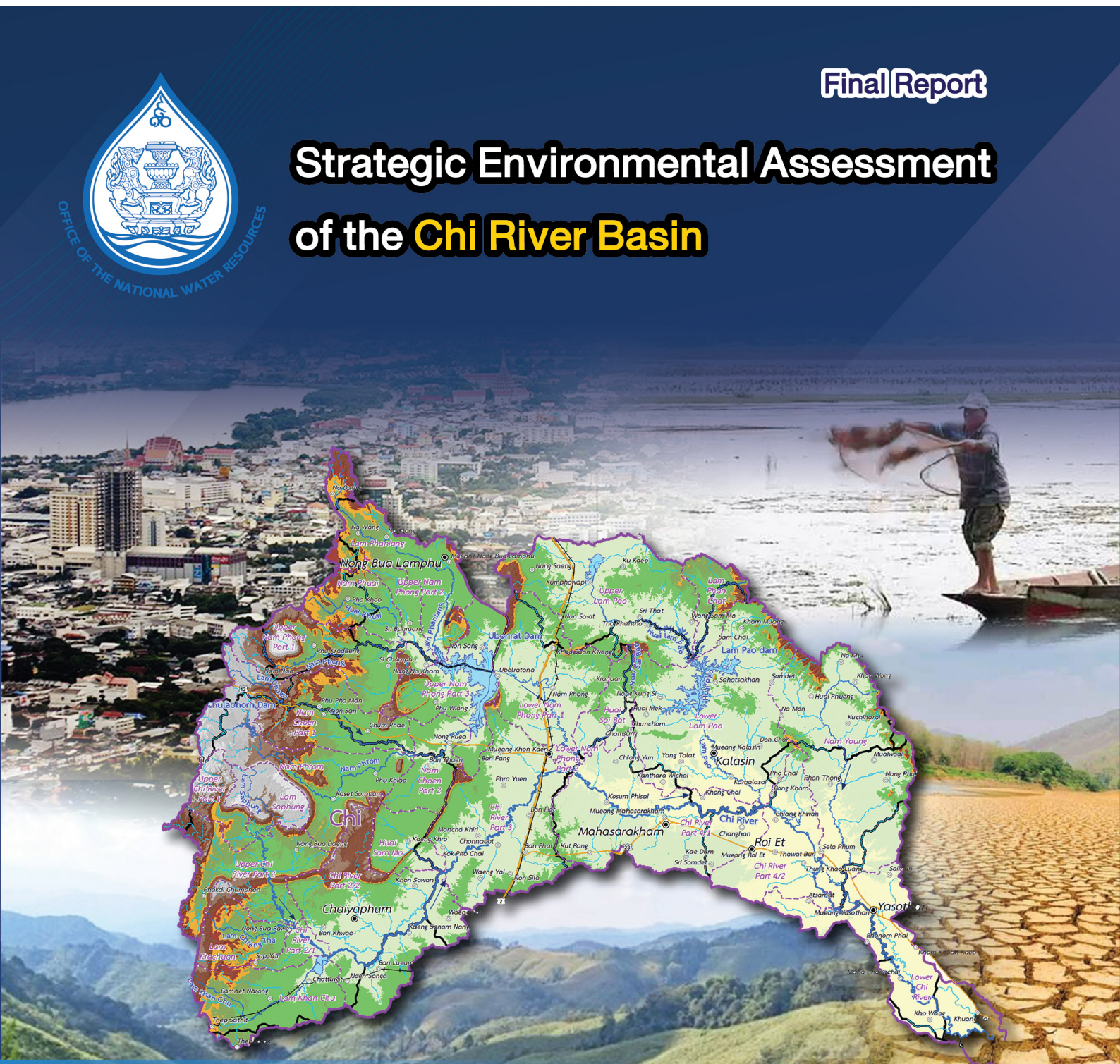
Final Report

Strategic Environmental Assessment of the Chi River Basin



Executive Summary Report
Strategic Environmental Assessment

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January 2020

Report Components

Strategic Environmental Assessment for the Chi River Basin

Final Report

Final Report

- **Strategic Environmental Assessment Report**
  - Executive Summary Report of the Strategic Environmental Assessment (Thai version)

- **Executive Summary Report of the Strategic Environmental Assessment (English version)**

  - Strategic Environmental Assessment Report
  - Impact Mitigation and Monitoring Measures Report
  - Appendices to the Strategic Environmental Assessment
    - Appendix (1/3)
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- **Strategic and Integrated Development Program Report**
  - Executive Summary Report, Strategic and Integrated Development Program Report (Thai version)
  - Executive Summary Report, Strategic and Integrated Development Program Report (English version)
  - Strategic and Integrated Development Program Report
  - Appendices to the Strategic and Integrated Development Program Report

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Symbols and Abbreviations

B.E.	=	Buddhist Era
Dec	=	December
e.g.	=	exempli gratia
EGAT	=	Electricity Generating Authority of Thailand
etc	=	et cetera
GDP	=	Gross Domestic Product
GPP	=	Gross provincial product
i.e.	=	in other words, that is, that is to say
IUCN	=	International Union for Conservation of Nature
Jun	=	June
km	=	kilometer
km^2	=	square kilometer
m	=	Meter
m^3	=	cubic meter
MCA	=	Multi Criteria Analysis
MCM	=	million cubic meter
mm	=	millimeter
MSL	=	Mean Sea Level
Nov	=	November
NWRC	=	National Water Resources Committee
ONWR	=	Office of the National Water Resources
OTOP	=	One Tambon One Product
PPPs	=	Policies Plans and Programs
PWA	=	Provincial Waterworks Authority
SDGs	=	Sustainable Development Goals
SEA	=	Strategic Environmental Assessment
SIDP	=	Strategic and Integrated Development Program
SMEs	=	Small and Medium Enterprises
SOAR Analysis	=	Strengths, Opportunities, Aspirations and Results Analysis
SWOT Analysis	=	Strengths, Weaknesses, Opportunities and Threats Analysis
TQM	=	Total quality management

Strategic Environmental Assessment of the Chi River Basin

1 Conditions and problems of the Chi River Basin

1. Conditions of the Chi River Basin

1.1) The Chi River Basin has an area of 49,130 km² or about 30.71 million rai covering 13 provinces.

1.2) The total forest area of Chi River Basin is 5.09 million rai and the agricultural areas span approximately 20.44 million rai.

1.3) The area composed of soils which is suitable for crop cultivation spans 19.56 million rai.

1.4) An average annual rainfall is 1,188 mm.

1.5) An average annual runoff is 11,994 MCM.

1.6) Population is 5,953,334.

1.7) Water demand in all sectors is 5,068 MCM.

1.8) The water storage capacity of local large- and medium-scale projects is only 5,687 MCM.

2. Problems of the Chi River Basin

2.1) The Chi River Basin area experiences the issues of flooding, drought and wastewater frequently.

2.2) Farmers and local residents have low income.

2.3) Labor migration

2.4) The average household income in the Chi River Basin is lower than the country's average.

2 Alternatives for the Development of the River Basin Area

Alternative 1: Business as usual

Alternative 2: The development for basic necessities and development of sustainable agricultural areas

Alternative 3: The management of water resource-related risks at the area level and the development of related agricultural industries

Alternative 4: The development of agroindustry in the northeast region

Alternative 5: The development of business agriculture as the center of the Greater Mekong Subregion

3 Alternative Proposal

Alternative 3: The management of water resource-related risks at the area level and the development of related agricultural industries – Processing and adding the value to agricultural products, organic farming, and provision of water to support existing industries. This alternative aims to address the issues of drought, flood and wastewater, especially protection of floods in main cities to reduce the income gap between rural and urban people.
It consists of short- and medium-term development plans in the Chi River Basin area.

Alternative 5: The development of business agriculture as the center of the Greater Mekong Subregion – This alternative involves the diversion of water from the Mekong River to increase irrigated agricultural areas to respond to the expansion of all types of industries, create the stability and security of water for agriculture, especially in the dry season, and add the value of water in production (business agriculture and exportation), and increase the country's GDP. It consists of medium- and long-term development plans in the Chi River Basin area.

4 Impact Mitigation and Monitoring Measures

Impacts

Positive impacts

1. Standard water quality
2. Ecosystem conservation
3. Water availability in rainfed agricultural areas
4. Improved coverage of agricultural areas with the water distribution system
5. Increase in dry and wet season cultivation areas
6. Solve wastewater problems
7. Reduced loss from flood
8. Increase water storage sources due to medium- and large-scale water source development in the basin areas
9. Increase water availability in the Chi River Basin

Negative impacts

1. Adverse effect on forest conservation areas
2. Costs and expenses
3. Farmers' learning about, and adaptation, in crop cultivation
4. Adverse effect on farmland and housing
5. Adverse effect of soil disposal areas from excavation of water conveyance canals
6. Use of a high construction budget amount

Impact mitigation measures

1. Establishment of an understanding among local people and affected people
2. Reforestation with double compensation for lost legal forest areas
3. Payment of fair compensations
4. Provision of areas for material disposal and improvement in line with the ecosystem

Monitoring measures

1. Economic: income, unemployment and labor migration
2. Social: compensation, people affected remedy and chemical risk monitoring
3. Environmental: reforestation, land use, water quality and organic famring

5 Integration of Chi River Basin development plans as the Center of the Greater Mekong Subregion

The integration of Chi River Basin development plans as the center of the Greater Mekong Subregion, and Chi River Basin management plans involves provision of sufficient, secure and stable water to provide an opportunity for economic development comprising:

1) Basic Problem Solving Program
2) Drought, Flood and Wastewater Mitigation Program
3) Water Source Development for Economic Development Program and water source project development of the Chi River Basin at full potential and Mekong River diversion to support plans for developing the Chi River Basin area to be a center of the Greater Mekong Subregion.

The strategic plans for water resource management must be integrated with the Chi River Basin development plans as follows:

1) Transport and logistics system development plans
2) Agricultural business development plans
3) Urban and tourism development plans

6 Driving plans into practice

The ONWR is a major agency to drive the development plans for water resources in the Chi River Basin continuously. The ONWR must formulate the plans into practice as follows:

1) Proposing the SEA/SIDP to the River Basin Committee and all relevant sectors to share comments for the ONWR to screen and present to the National Water Resources Committee and the Cabinet, respectively.
2) Driving the development plans for water resources in the Chi River Basin requires the clarity of the programs/projects under the six aspects in relation to coordination and integration of work between responsible agencies, impact assessment and monitoring, implementation assessment and monitoring, and adjustment of plans in lien with existing situations and problems.
3) The management of bid data to be used for systematic water resource management comprises three components, namely (1) water resource data systems (2) supporting components, e.g. participatory networks, agencies and development plans in the river basin, information systems to support water resource management and (3) laws and regulations for water resource management.
4) The management of the big data on water resources, which is in line with the new approach to high performance organization.

Executive Summary Report
Strategic Environmental Assessment Report of the Chi River Basin

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Introduction

Chapter 1
Introduction

1.1 Background

The Chi River Basin spans approximately 49,130 km^2, which is approximately 30,706,152 rai (30.71 million rai). It covers 13 provinces, namely Kalasin, Khon Kaen, Chaiyaphum, Nakhon Ratchasima, Phetchabun, Maha Sarakham, Yasothon, Roi Et, Si Sa Ket, Nong Bua Lam Phu, Udon Thani, and Ubon Ratchathani. Almost all the river basin area is in Chaiyaphum, Khon Kaen, Kalasin and Roi Et provinces, respectively, with a population of approximately 5,953,334 (5.95). It has an average annual rainfall of 1,188 mm and an average annual runoff of 11,994 MCM. The water demand by all sectors amounts to 5,068 MCM; however, the water storage capacity of local large- and medium-scale projects is only 5,687 MCM. Thus, the Chi River Basin always experiences water issues. Top-priority water-related problems include the shortage of water for agriculture, shortage of water for domestic use, flooding in urban and agricultural areas, and water quality issues. The Chi River Basin comprises a total forest area of approximately 5,091,486 rai (5.09 million rai), which represents 16.58 percent of the river basin area, and comprises a total agricultural area of approximately 20,436,852 rai (20.44 million rai), representing 66.56 percent of the river basin area.

Given the current conditions of the Chi River Basin, the Office of the National Water Resources has realized the need for the study of the Chi River Basin Strategic Environmental Assessment. This aimed to assess environmental potential and constraints for the management of water resources in the Chi River Basin area which can result in balance and sustainable development in economic, social and environmental dimensions. This also aimed to compare alternatives for the management of water resources in the Chi River Basin area to ensure prudent decision-making and maximum benefits for the country and the general public. This is in line with the strategic issue for the development the river basin system-based water management to increase the country's water security.

1.2 Location and Characteristics of Study Areas

The Chi River Basin is situated in the northeast region of Thailand, lying between 15º 30´ north latitude and 17º 30´ north latitude and between 101º 30´ east longitude and 104º 30´ east longitude. It comprises 27 sub-basins, with the Chi River as the main river, and different tributaries, e.g. Nam Phrom, Nam Choen, Nam Phong, Nam Pao, and Nam Yang. It mostly covers middle northeastern provinces and partly covers upper northeastern provinces, with these boundaries:

North: Connected to the Mekong River Basin.

South: Connected to the Mun River Basin.

East: Connected to the Mekong River Basin and the Mun River Basin.

West: Connected to the Pa Sak River Basin.

The topography of the Chi River Basin comprises high mountain ranges to the east and north, which are the Phu Phan mountain ranges; and to the west are the Phetchabun mountain ranges and the Dong Phaya Yen Forest, where the Chi River and various tributaries originate. Its middle area consists of plains and undulating areas with slight slopes to the south of the river basin, with the Chi River as the main river. The Chi River originates in the Phu Khiao mountain ranges in the Phu Khiao Wildlife Sanctuary at Ban Lon, Nang Daet Sub-district, Nong Bua Daeng district, and then flows to the southeast through Chaturat and

Mueang Chaiyaphum Districts, Chaiyaphum province. Next, it goes back to the northeast through Khon Sawan District, Chaiyaphum Province, and Mancha Khiri District, Mueang Khon Kaen District, Khon Kaen Province. It goes back to the southwest through Kosum Phisai and Mueang Maha Sarakham districts, Maha Sarakham Province; Selaphum and Phanom Phrai districts, Roi Et Province; Mueang Yasothon and Maha Chana Chai districts, Yasothon Province; and Khueang Nai District, Ubon Ratchathani Province. After that, it flows and meets with the Mun River in Mueang Ubon Ratchathani District, Ubon Ratchathani Province. Its total length is approximately 830 km. The Chi River Basin's general topography is illustrated in **Figure 1.2-1**.

1.3 Objectives of the Study

The objectives of the Project are as follows**:**

1) To study and prepare the report on the strategic environmental assessment (SEA) on the management of water resources in the Chi River Basin.

2) To study and prepare the report under the Strategic and Integrated Development Program (SIDP) of the Chi River Basin.

3) To study and develop the database on the Chi River Basin for the Office of the National Water Resources and the River Basin Committee for water management, river basin plan formulation, decision-making, and provision of information for water users and the general public.

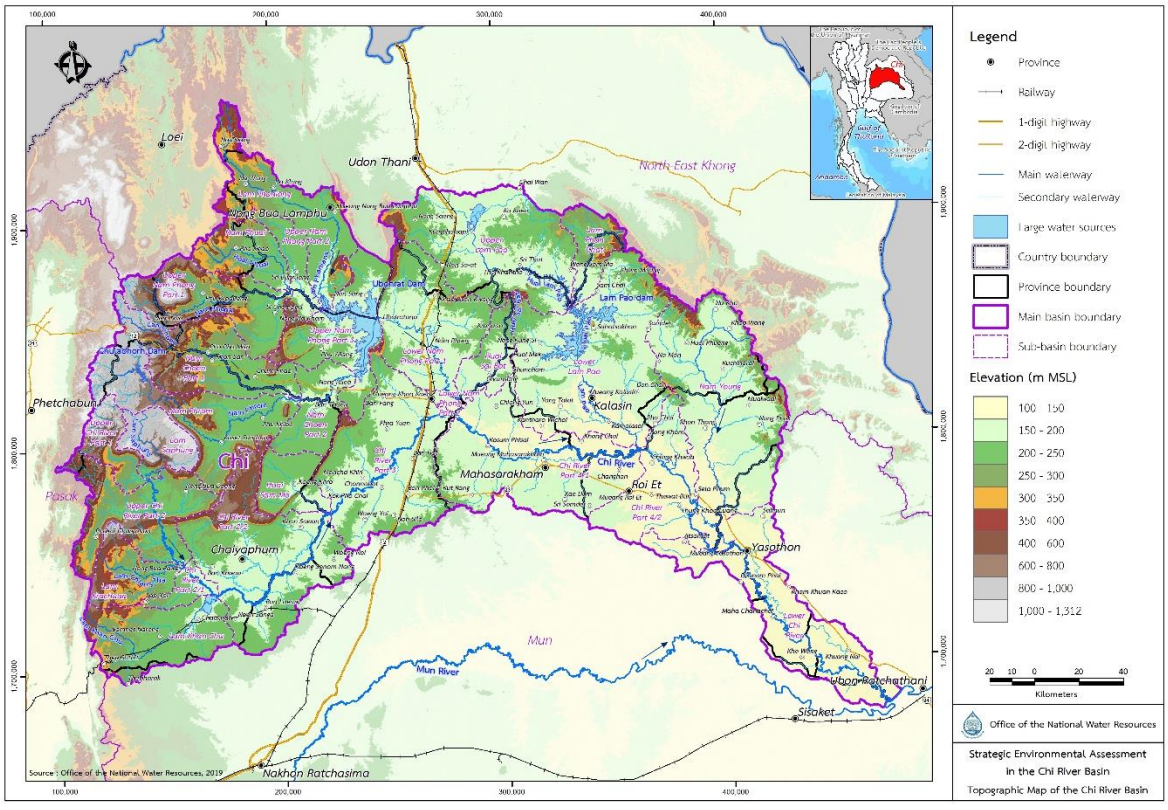


Figure 1.2-1 Area Conditions and Sub-basins of the Chi River

Chapter 2

Scoping

Chapter 2
Scoping

The development covers all Chi River Basin areas. Thus, it affects development plans at the national, regional and provincial levels. The concept of "**management that is in accordance with the National Strategy and the 20-Year Master Plan on Water Resources Management, B.E. 2561-2580 (2018-2037)** was outlined. Relevant programs were reviewed and analyzed as summarized below.

2.1 Situations and Trends of Changes Affecting the Chi River Basin Area

To ensure the consistency and efficiency of the national, regional, and river basin area development, the strategic issues for economic, social and environmental development in relation to the Chi River Basin were reviewed, which included the Master Plans under the National Strategy, regional development plans related to the river basin areas, national development plans identified in the 12th National Economic and Social Development Plan, B.E. 2560-2564 (2017-2021), and provincial cluster development plans, as outlined below:

1) Economic development directions consist of the five key development issues, as follows:

1.1) Enhancement of the potential of agricultural production to meet organic farming and food safety standards.

1.2) Development of processed agroindustry to high-value products.

1.3) Strengthening and enhancement of the competitiveness of the production and service sectors.

1.4) Reduction in economic inequality.

1.5) Economic restructuring.

Development directions are detailed in **Table 2.1-1**.

2) Social development directions consist of the six key development issues, as follows:

2.1) Change in the general public's value which ensures that they are equipped with morality, ethics, discipline, public mind, and desirable behavior.

2.2) Development of human potential to ensure they have skills, knowledge and abilities to live valuable life.

2.3) Reduction in health risk factors and encouragement of all sectors to be aware of health impacts.

2.4) Development of the systems for environmental maintenance and create the environment conducive to the aging society.

2.5) Comprehensive and thorough distribution of high-quality public educational, health, and welfare services.

2.6) Strengthening of community potential, community economic development, and foundation finance based on the sufficiency economy philosophy to allow them to be self-reliant and empower them to manage community capital, land and resources.

Development directions are detailed in **Table 2.1-2**.

3) Environmental development directions consist of the six key development issues, as follows:

3.1) Increase in water management efficiency for sustainable development.

3.2) Restoration of forest resources to maintain their abundance and preservation of biodiversity in watershed areas in Loei, Udon Thani, Sakon Nakhon, Chaiyaphum and Nakhon Ratchasima provinces.

3.3) Maintenance and rehabilitation of natural resources and creation of balance between conservation and utilization in a sustainable and fair manner.

3.4) Promotion of environmentally-friendly production and consumption.

3.5) Support for the reduction of greenhouse gas emissions and enhancement of climate change.

3.6) Management for disaster risk mitigation.

Development directions are detailed in **Table 2.1-3**.

Table 2.1-1 Economic Development Issues Related to the Chi River Basin Areas

Development issues	Development directions
1. Enhancement of the potential of agricultural production to meet organic farming and food safety standards.	1) Develop Thung Kula Rong Hai areas in Yasothon, Roi Et, Maha Sarakham and Si Sa Ket provinces as high-quality jasmine rice cultivation sources 2) Promote changes to new agricultural products to suit area potential, e.g. Loei and Si Saket provinces, which promote vegetables, fruits and flowers cultivation
2. Development of processed agroindustry to high-value products.	1) Develop Nakhon Ratchasima City as the center of processing agricultural industry and complete food 2) Promote small-scale industry that produces consumer products in areas linking to economic corridor areas in Chaiyaphum, Khon Kaen, Kalasin and Roi Et provinces to be exported to neighboring countries 3) Increase the potential of renewable energy production in central northeastern provincial clusters
3. Strengthening and enhancement of the competitiveness of the production and service sectors.	1) Develop the agricultural sector by (1) strengthening its production base to become strong and sustainable, (2) creating and transferring participatory agricultural knowledge on academics, science, technology, innovation and local wisdom, (3) upgrading agricultural products and food to meet the standard in line with the market demand and food consumption for health, 4) enhancing the manufacturing potential in the agricultural industry chain, (5) promoting and expanding the agricultural concept in accordance with the sufficiency economy principle and, (6) developing support factors for management of the agricultural sector and supporting new generation farmers. 2) Develop the industrial sector by (1) extending the current potential industrial strengths to upgrade it to the industry using high technology and (2) laying foundation of future industrial development, e.g. automatic robot industry, manufacturing of medical equipment and devices, etc. 3) Develop in the tourist sector by (1) enhancing the former and new service bases of business competitiveness of the service sector to promote the country's economic growth and (2) developing the integrated tourist industry 4) Develop the trade and investment sectors by (1) supporting business operators in investing in the information technology and communication systems (2) promoting medium- and small-scale enterprises and (3) developing support factors to promote local investment and promote Thai people's investment in foreign investment countries
4. Reduction in economic inequality.	1) Distribute economic growth and opportunity to the region and local levels thoroughly 2) Decentralize power to local areas so that they can determine the development direction as required
5. Economic restructuring.	1) Switch from the production of commodities to innovative products 2) Change from driving the country using the industrial sector to technology, creativity and innovation 3) Change from more emphasis on the manufacturing sector to the service sector

Source : - The Master Plan under the National Strategy (Office of the National Economic and Social Development Council), 2019
- The 12th National Economic and Social Development Plan (Office of the National Economic and Social Development Council), 2016
- Provincial and provincial cluster development plans (Ministry of Interior), 2017

Table 2.1-2 Social Development Issues Related to the Chi River Basin Areas

Development issues	Development directions
1. Change in the general public's value which ensures that they are equipped with morality, ethics, discipline, public mind, and desirable behavior.	1) Strengthen communities to take part in organizing public benefit activities, arrange social order and impose penalties to those who violate social norms 2) Encourage the adoption of desired work culture as characteristics of people in the society
2. Development of human potential to ensure they have skills, knowledge and abilities to live valuable life.	1) Promote workers' knowledge and skills to meet the labor market demand 2) Develop the potential of elderly group to enter the job market
3. Reduction in health risk factors and encouragement of all sectors to be aware of health impacts.	1) Develop people with knowledge in health care, health consciousness and self health screening behaviors 2) Encourage people to have health activities suitable for their ages both exercise and proper nutrition 3) Push for a mechanism for health impact assessment in preparation for public policies based on the concept of all policies concerned about health from the national, area and community policies
4. Development of the systems for environmental maintenance and creation of the environment conducive to the aging society.	1) Develop the medium-term health systems to serve those who need to recover before returning home linking the long-term health care systems 2) Promote urban development that is friendly to elderly people in terms of public transport systems, buildings, public areas and residential areas contributing to livelihood of elderly people and all groups in the society
5. Comprehensive and thorough distribution of high-quality public educational, health, and welfare services.	1) Promote the distribution of quality educational services to be more equal among areas 2) Manage public health services to be of good quality covering all areas 3) Improve business environmental factors, including law and regulations to create fair competition
6. Strengthening of community potential, community economic development, and foundation finance based on the sufficiency economy philosophy to allow them to be self-reliant and empower them to manage community capital, land and resources.	1) Build and develop leaders to change communities and have potential for inspiring people to have confidence, faith, ideology and good governance in community management and development 2) Encourage community gathering and awareness in self-reliance, as well as community economic development 3) Support communities to participate in welfare management and services, as well as resource management in communities in the form of partnership with public agencies and local administrative organizations in people's quality of life

Source : - The Master Plan under the National Strategy (Office of the National Economic and Social Development Council), 2019
- The 12th National Economic and Social Development Plan (Office of the National Economic and Social Development Council), 2016
- Provincial and provincial cluster development plans (Ministry of Interior), 2017

Table 2.1-3 Environmental Development Issues Related to the Chi River Basin Areas

Development issues	Development directions
1. Increase in water management efficiency for sustainable development.	1) Develop the existing and natural water sources to increase the storage efficiency 2) Develop new water sources in the Chi River Basin and produce monkey cheek areas, reservoirs, weirs and small-scale water sources in suitable areas/agricultural areas
2. Restoration of forest resources to maintain their abundance and preservation of biodiversity in watershed areas in Loei, Udon Thani and Chaiyaphum provinces.	Specify and mark the boundary of conservation areas and non-conservation areas by focusing on public participation in rehabilitation, forestation and encroachment prevention to conserve watershed forests, prevent from soil erosion, conserve wetlands and promote community forests to bring about sustainable benefits from forests
3. Maintenance and rehabilitation of natural resources and creation of balance between conservation and utilization in a sustainable and fair manner.	1) Restore forest resources to create natural balance 2) Conserve and benefit from the biodiversity 3) Plan mineral resource management to bring about maximum benefits and mitigate impacts on the environment and people
4. Promotion of environmentally-friendly production and consumption.	1) Promote production and investment in the environmental friendly industrial sector 2) Support production in the agricultural sector to sustainable agriculture
5. Support for the reduction of greenhouse gas emissions and enhancement of climate change resilience.	1) Develop measures and mechanisms that support greenhouse gas reduction in all sectors 2) Promote the private sector, state enterprises and local administrative organizations to store and report information about greenhouse gas emission
6. Management for disaster risk mitigation.	1) Develop disaster management systems in emergency 2) Develop post-disaster rehabilitation systems 3) Promote knowledge on disaster management

Source : - The Master Plan under the National Strategy (Office of the National Economic and Social Development Council), 2019
- The 12th National Economic and Social Development Plan (Office of the National Economic and Social Development Council), 2016
- Provincial and provincial cluster development plans (Ministry of Interior), 2017

2.2 Objectives, Goals and Indicators

2.2.1 Objectives and Goals

Concerning the determination of objectives, goals and directions of river basin development based on economic, social and environmental consistency, as well as development sustainability according to the principle of integrated water resource management (IWRM Approach) as specified in the study guideline (**Chapter 1** Strategic Environmental Assessment Report), the objectives have been determined in this study to ensure development and appropriate alternative assessment involved considering comprehensive different dimensions, i.e. upstream, midstream, downstream, as well as water, soil, forest, surface water and groundwater resources in qualitative and quantitative terms; mitigation of water disasters, including drought, flood and wastewater; demand-supply balance; appropriate structural and non-structural water management; and different levels of stakeholders.

The goals of the local development are set by considering the compliance with the national 20-year strategy and the northeastern development approach according to the 12th National Economic and Social Development Plan. The development goals in this study are determined to improve the quality of life of farmers and people in the Chi River Basin area, increase their incomes, and develop the local economy to ensure stability, prosperity and sustainability, covering economic, social and environmental dimensions, as follows:

1) Economic dimension – Improvement of the incomes and quality of life of people in the Chi River Basin area.

1.1) Enhancement of water use stability and security by providing adequate water availability for different activities and delivery of water to irrigated areas and beneficiary areas spanning 10 million rai.

1.2) Increase of the gross domestic products and income per household in the Chi River Basin to ensure that they are not below the country's averages.

2) Social dimension: Thorough development distribution and people's improved access to water.

2.1) Provision of all villages with standard-quality water for domestic use and efficient water use.

2.2) Provision of water to rainfed agricultural areas to increase farmer incomes, improve their quality of life, and reduce damage to critical areas by 50.00 percent.

2.3) Mitigation of the issues of drought, flooding and wastewater in different areas of the Chi River Basin and bank erosion along the Chi River.

3) Environmental dimension – Environmental balance-based development.

3.1) Conservation and rehabilitation of watershed forests and economic forests representing 20.00 percent of the river basin area and restoration of natural water bodies to ensure their abundance, ecosystem balance for the Chi River Basin area, and maximum benefits from utilizing water from water bodies.

3.2) Development of water source projects taking into account environmental balance and sustainable development.

2.2.2 Indicators

To develop appropriate water resource management alternatives in river basin areas, it is necessary to assess benefits and impacts according to key indicators in terms of economic, social and environmental dimensions in line with the river basin context, including assessment of accumulated impacts. These indicators are used to monitor impacts in the future. At least, these indicators had to meet the eight objectives of "The Analysis of Indicators for Spatial Strategic Environmental Assessment: River Basin Management Plan," prepared by the Office of the National Water Resources (2018), as presented in **Table 2.2.2-1**.

Table 2.2.2-1 Indicators for the Alternatives by Dimensions

Economic dimension	
Goals	**Indicators**
1. Increase in products and services.	1.1 Change in water availability. 1.2 Beneficiary areas. 1.3 Water footprint in the production sector.
2. Poverty reduction.	2.1 Increase in GPP per capita. 2.2 Loss of GPP due to water disasters.
3. Fair income distribution.	3.1 Number of local SMEs. 3.2 Use of local raw materials and workers.
Social dimension	
Goals	**Indicators**
4. Response to basic needs.	4.1 Population with water access. 4.2 Population with hydro energy access.
5. Fairness.	5.1 Population that migrates in case of development. 5.2 Number of people affected by water disasters.
6. Equality.	6.1 Participation in proposing alternatives. 6.2 Number of affected cultural and natural heritages. 6.3 Access to water management-related data.
Environmental dimension	
Goals	**Indicators**
7. Sustainable resource use.	7.1 Amount of recycled water. 7.2 Percentage of changed forest areas. 7.3 Size of restored forest areas.
8. Conservation of natural resources and the environment.	8.1 IUCN Red List Index. 8.2 Percentage of improved waterways, including: 8.2.1 Number of obstacles along the waterways. 8.2.2 Distance of dredged ways.

Source : The Office of the National Water Resources, 2018.

Chapter 3

Current and Next 20-Year Situation Analysis in the Chi River Basin

Chapter 3
Current and Next 20-Year Situation Analysis in the Chi River Basin

3.1 Conditions of the Chi River Basin

3.1.1 River Basin Conditions in General

1) Location: The Chi River Basin is in the northeastern region of Thailand (Isan). The total basin area is 49,130 km^2 or about 30,706,152 rai (30.71 million rai), as illustrated in **Figure 3.1-1**.

2) Topography of the Chi River Basin is composed of the Phu Phan mountain ranges, which are high mountain ranges to the east and north, and the Phetchabun mountain ranges and the Dong Phaya Yen Forest to the west. Its middle area is characterized as flat areas and slightly slopes to the south of the river basin. The general topography of the Chi River Basin is illustrated in **Figure 3.1-1**.

3.1.2 Meteorology and Hydrology

1) Climate – In general, the Chi River Basin is influenced by the southwest and northeast monsoons. Each year, it is also under the influence of depressions from the South China Sea, which results in heavy rain during the wet season. The influence of both monsoons brings about three seasons – hot season, wet season, and cold season, with the average annual temperature of approximately 27 degrees Celsius, with monthly mean values ranging from 23.4 to 29.8 degrees Celsius. Its average annual relative humidity represents approximately 73.8 percent, with monthly mean values ranging between 64.0 and 83.9 percent. Its average annual evaporation is approximately 1,566.2 mm, with monthly mean values ranging between 111.3 and 172.5 mm.

2) Rainfall – Based on the monthly rainfall data derived from 204 rainfall gauging stations in the Chi River Basin area, an analysis was analyzed on the isohyet of the annual rainfall. The average annual rainfall in the Chi River Basin is 1,188 mm. Based on the analysis of 30-year rainfall data from 165 rainfall gauging stations in provinces where the Chi River Basin is located, the average rainfall in all provinces was lower than Thailand's average[1]. The Chi River Basin area experiences a prolonged no-rainfall period during the wet season, which has an impact on agricultural products.

3) Runoff – The runoff data from 57 runoff stations, as shown in **Figure 3.1-2** was used to analyze the runoff in the Chi River Basin, which comprises a catchment area of 49,130 km^2. Its total average annual runoff equates to 11,993.64 MCM, with 10,449.55 MCM in the wet season (May to October), representing 87.13 percent of the average annual runoff, and 1,544.08 MCM in the dry season (November to April). The average runoff is the highest in September, which amounts to 3,823.43 MCM and the lowest in March, which amounts to 84.80 MCM. The total amount of runoff in August, September and October is 8,435.22 MCM, which represents 70.33 percent of the average annual runoff. Thus, it is necessary to develop reservoirs in the river basin to store excess water in the three months for utilization in the dry season. The average annual runoff per unit area for the 27 sub-basins ranges between 4.26 and 12.36 liters per second per km^2.

[1] Thailand's annual average rainfall: 1,425.7 mm (Department of Water Resources, 2007).

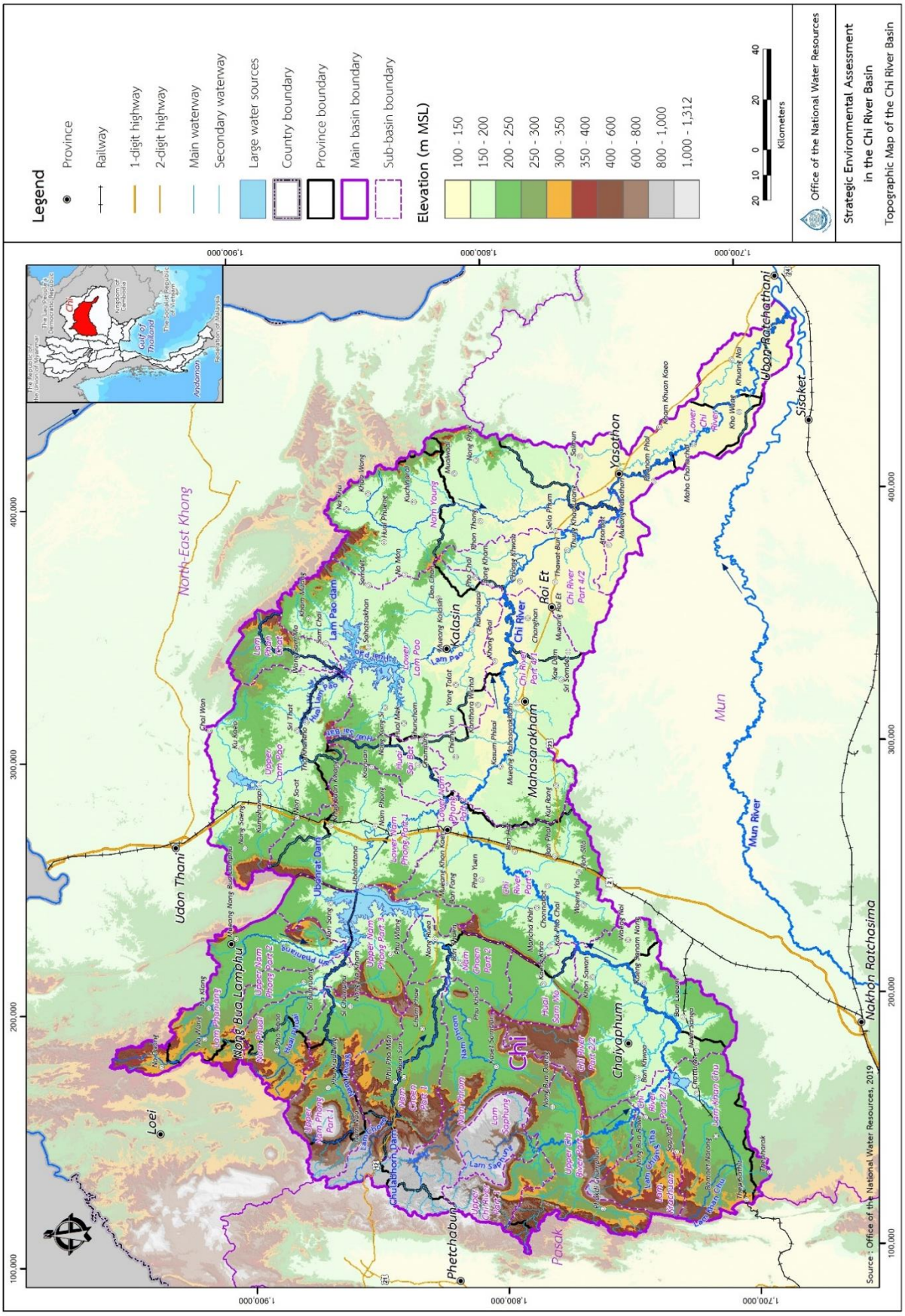


Figure 3.1-1 Topography of the Chi River Basin

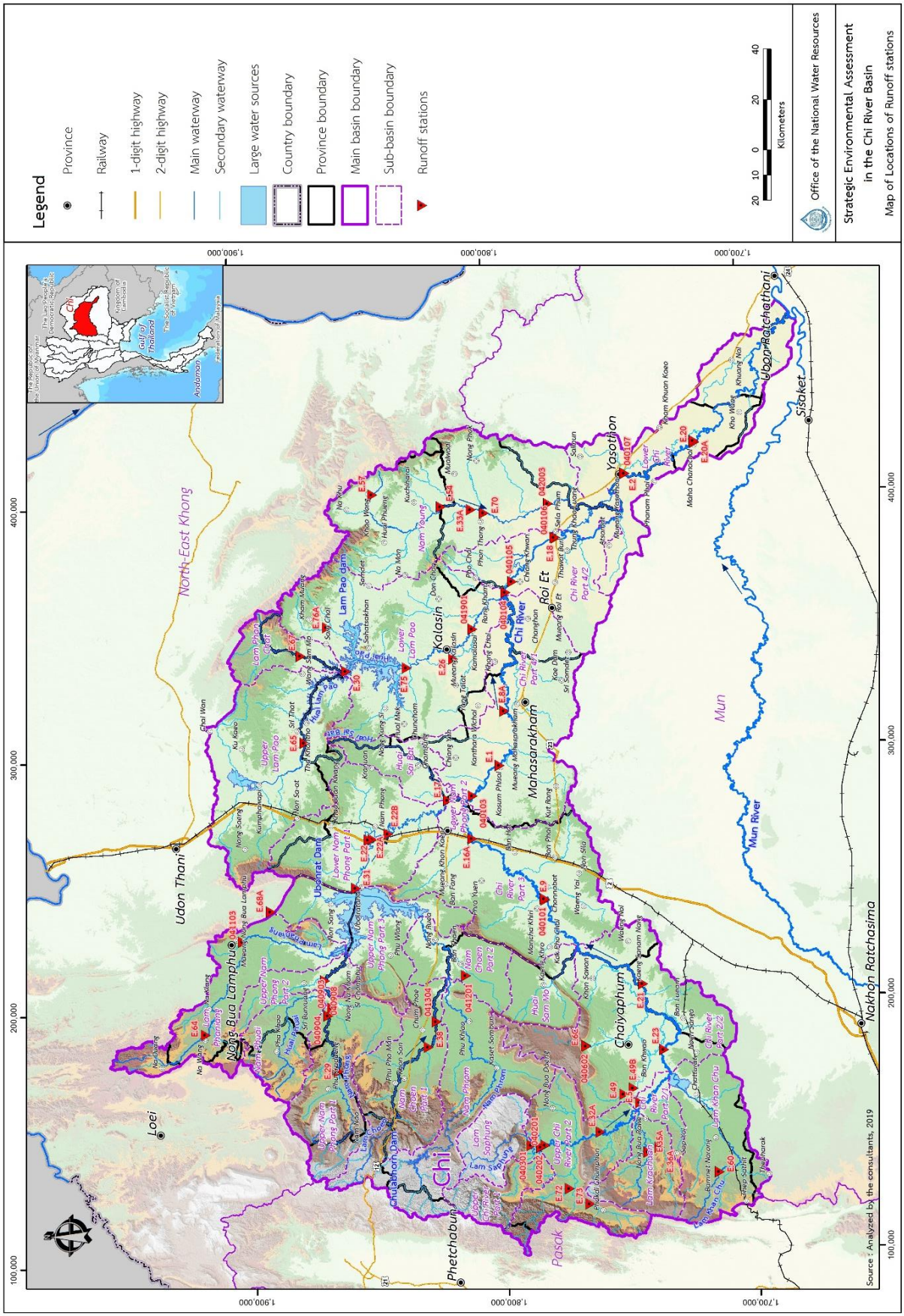


Figure 3.1-2 Locations of Runoff Stations in the Chi River Basin

4) Flood – The physical characteristics of the Chi River, including the widths of the streams and the weirs which block the Chi River, are the key factors in the inconsistency of the maximum flash flood rates of the runoff stations in the Chi River. Floods at the downstream gauging stations may be lower than those at the upstream gauging stations. Because the floods which flow through the upstream stations overflow the river banks and affect flood plains along both banks of the river, the floods flowing through the downstream stations have a decreased flow rate, as illustrated in **Figure 3.1-3.** The amount of flood flowing through the Station E.32A along the width of the Chi River will overflow both sides of the Chi River banks before flowing into the Station E.23A, resulting in reduced flow rates.

5) Sediment – The study of the sediment amount involved the collection of data on monthly and annual sediment from 32 sediment gauging stations in the Chi River. For the inspection, the representatives of the upstream, midstream and downstream areas were selected.

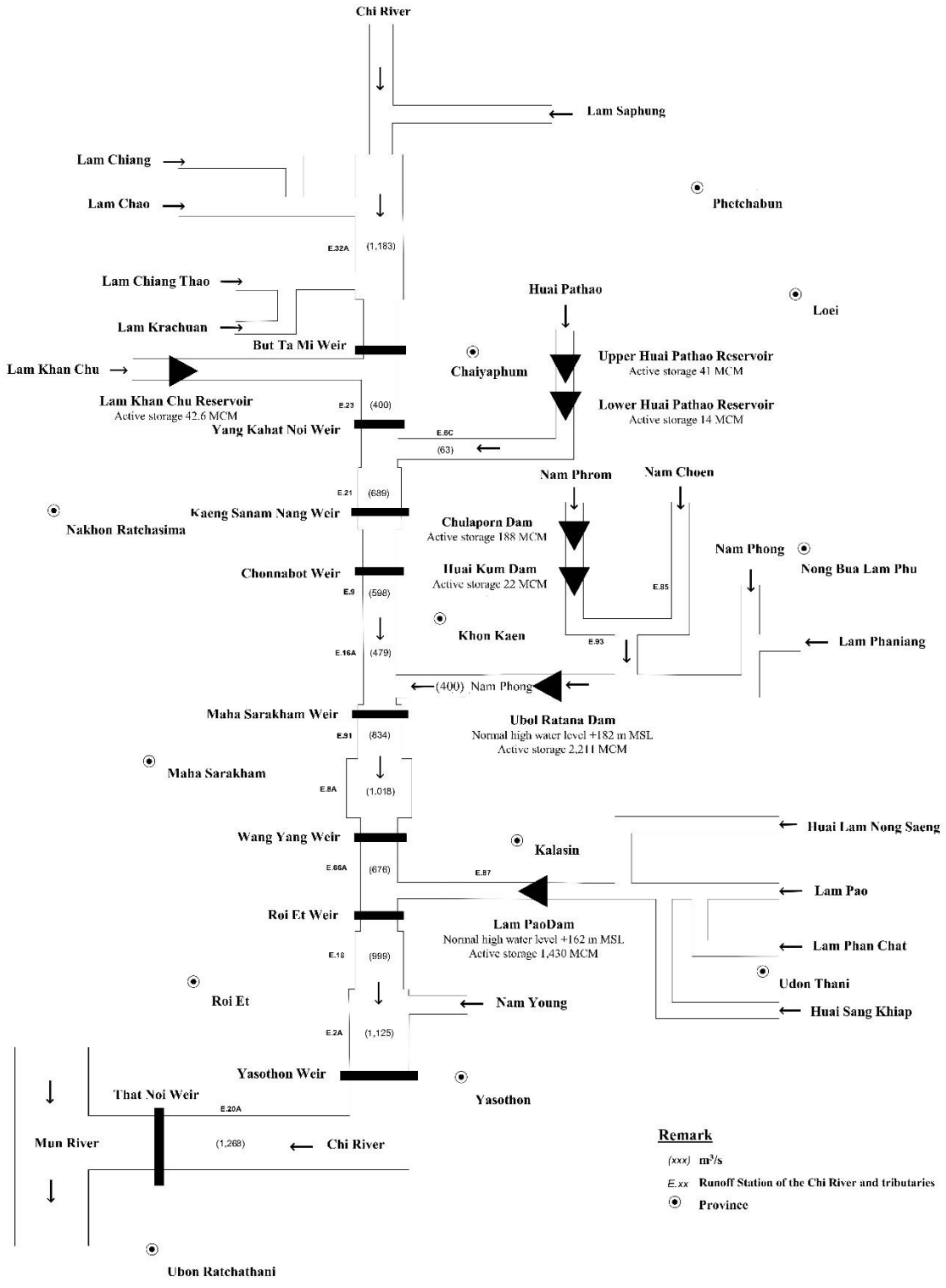
5.1) Analysis of the relationship between sediments and catchment areas – The sediment from 32 stations was used to analyze the relationship between suspended sediments and catchment areas indicated that the sediments measured at sediment gauging stations in the Chi River was scattered because the Chi River is wide and narrow different in each section, which affected the water flow and sediments in the Chi River Basin. It is notable that the sediments in upstream areas have catchment areas less than 5,000 km^2. This amount is relatively high compared to that of midstream and downstream areas.

5.2) Sediments in the Chi River Basin – Based on the monthly sediments at sediment gauging stations in the Chi River Basin and its sub-basins, suspended sediments per area unit were analyzed, as shown in **Figure 3.1-4**. It is summarized that the erosion is very severe in upstream areas: Young and Lam Pao river basins; severe in middle areas of the Young and Phong river basins; moderate in the first part of the Choen River Basin, Lam Phaniang, the 2/1 part and the 4/2 part of the Chi River Basin; and low in the major Chi River in the first upper part of the Chi, second part of the Chi, second part of the Choen, the third part of the Chi, the 4/1 part of the Chi and the lower Chi River. To reduce sediments in the Chi River Basin, watershed forest areas should be conserved and rehabilitated. Cover crops should be also planted in severe and moderate erosion areas.

3.1.3 Hydrogeology and Groundwater

The hydrogeological conditions of the Chi River Basin are mostly characterized as aquifers in consolidated rocks, which represent 91.99 percent of the river basin area, aquifers in unconsolidated rocks, representing 6.73 percent, and water bodies. Mostly, they are Maha Sarakham aquifers, which span an area of 8,196 km^2 (5.12 million rai), representing approximately 19.42 percent of the river basin area. The depths of the aquifers in the Chi River Basin range from 10-60 m, and they can reach 50-100 m in some sections of unconsolidated aquifers. Largely, their water yield capacity ranges from 2-10 m^3 per hour.

Based on the collected data on groundwater levels (Department of Groundwater Resources, 2009), groundwater elevation maps and groundwater flow directions were developed, as shown in **Figure 3.1-5**. Mainly, the groundwater flows from west, with higher topography, to lowland areas along the tributaries and flows from the west to the east along the flow direction of the Chi River.



Source : Analyzed by the consultants, 2019

Figure 3.1-3 Chart of the Chi River Storage

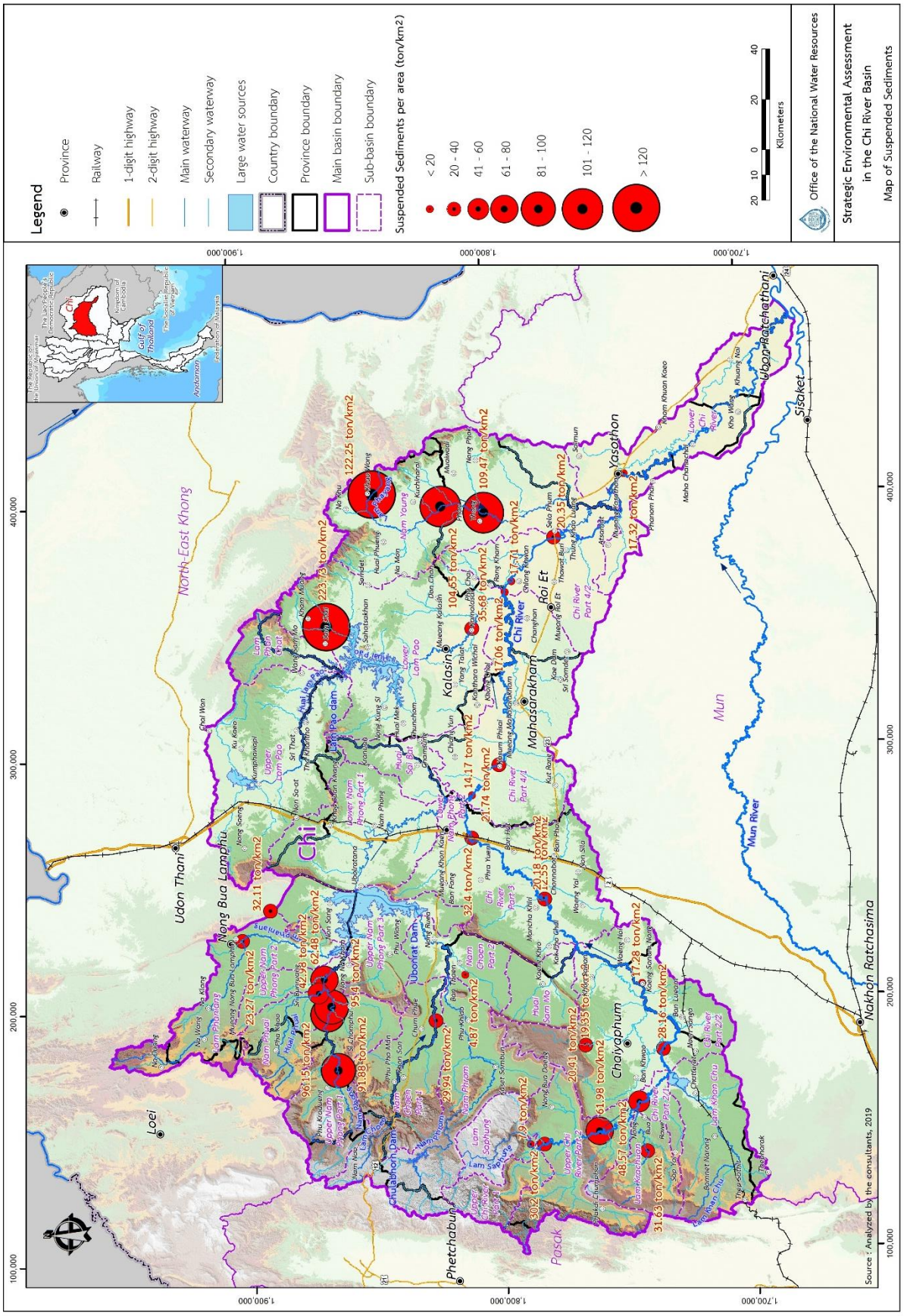


Figure 3.1-4 Suspended Sediments in the Chi River Basin

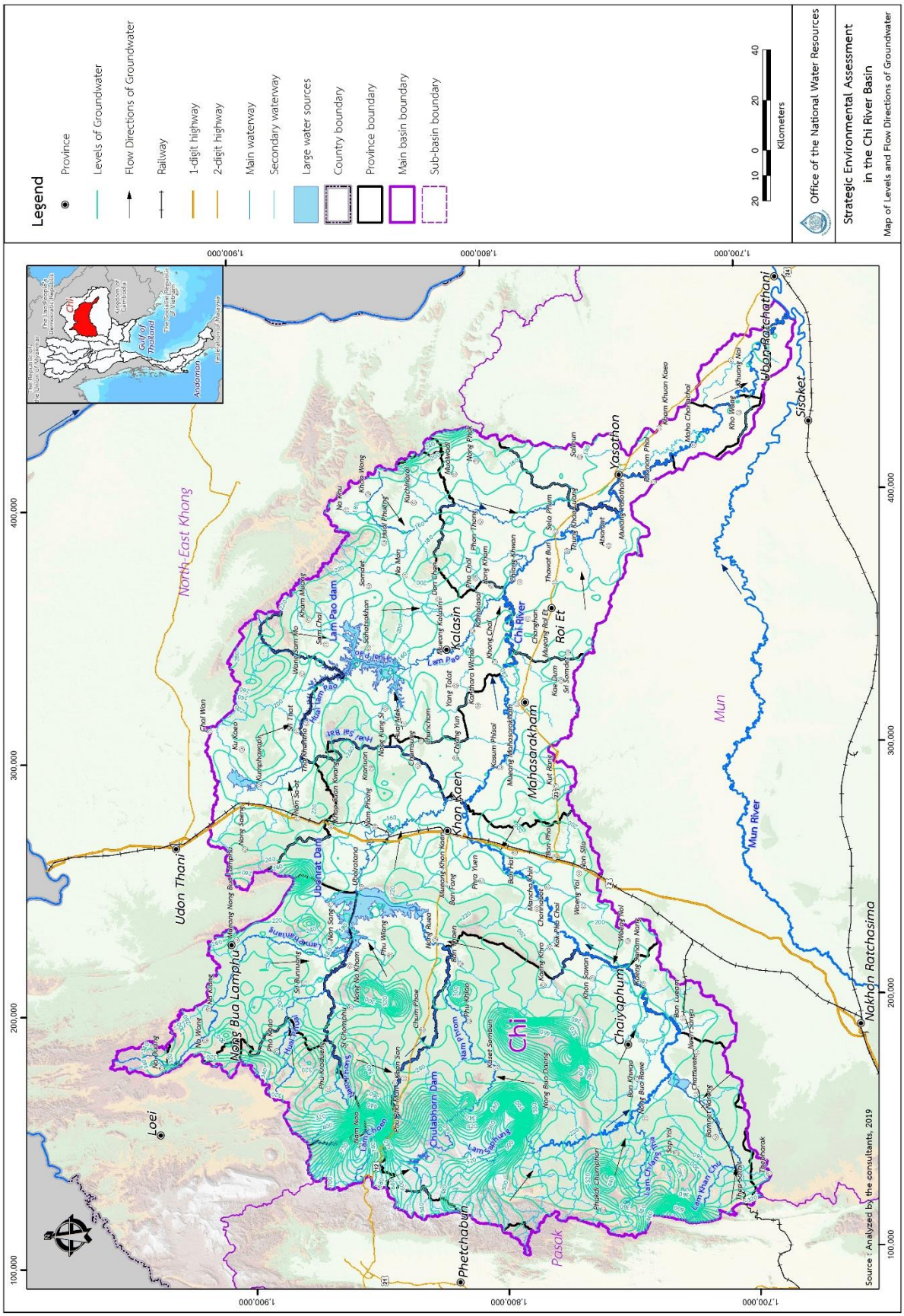


Figure 3.1-5 Levels and Flow Directions of Groundwater

3.1.4 Water Quality

The major surface water sources of the Chi River Basin consist of the Chi River, the Phong River, and the Lam Pao River. Given the surface water quality monitoring data from the Pollution Control Department and the water quality monitoring locations shown in **Figure 3.1-6** between 2013 and 2018, it can be concluded that the quality of water in these three rivers mostly meets the Class III Surface Water Standard: Water which can be used for consumption but must pass customary disinfection and customary water treatment and used for agriculture. The quality of water in the Chi and Phong Rivers is in line with the Pollution Control Department's Notification on Types of Water Sources in the Phong River, Chi River, Mun River, and Lam Takong River dated 31 March 1999, which specifies that the Chi River and Phong River are classified as Class III Surface Water. As for the Lam Pao River, its quality is not in line with the Pollution Control Department's Notification, whereby it is classified as Class II Surface Water (The Pollution Control Department's Notification on Types of Water Sources in the Lam Pao River, Dated 24 December 2008).

3.1.5 Soil Resources and Land use

1) Soil resources – Most of soil resources in the Chi River Basin have a relatively high soil development rate, which results in low natural fertility. The soil resources found in the Chi River Basin area consist of soil in lowland or flat areas, spanning 6,368,408 rai (6.37 million rai), soil in highland in dry soil areas spanning 17,404,824 rai (17.40 million rai), and soil in highland areas spanning 4,978,451 rai (4.98 million rai), which are scattered in different provinces in the Chi River Basin.

2) Land use – Land use in the Chi River Basin can be divided, according to land use conditions, into five major types: community and building area, agricultural area, forest area, water body, and miscellaneous area. The Chi River Basin area covers approximately 30,706,152 rai (30.71 million rai), which mostly comprises agricultural areas 20,436,852 rai (20.44 million rai), which represents 66.56 percent of the river basin area, followed by forest areas, with 5,091,486 rai (5.90 million rai), representing 19.21 percent. Each type of land use is scattered around the different provinces in the Chi River Basin.

3) Change in land use conditions – The data of land use in 2002 and 2016 for the Chi River Basin, which spans approximately 30,706,152 rai (30.71 million rai), is illustrated in **Table 3.1-1** and **Figure 3.1-7**. Given the comparison of land use conditions during that period, there is an upward trend for community and building areas and water bodies but a downward trend for agricultural, forest and miscellaneous areas (**Figure 3.1-8**).

4) Agriculture – Agricultural areas is the land use type with the most areas in the Chi River Basin. The total area is 20,436,852 rai (20.44 million rai). Most agriculture includes rice cultivation areas 11,729,674 rai (16.73 million rai), or 57.39 percent of the total agricultural area, followed by field crops: sugarcane 4,011,687 rai (4.01 million rai) or 19.63 percent, cassava 2,427,985 rai (2.43 million rai) or 11.88 percent, maize 206,467 rai (0.21 million rai) or 1.01 percent, perennial trees: rubber 917,965 rai (0.91 million rai) or 4.49 percent, eucalyptus 529,483 rai (0.52 million rai), or 2.59 percent and fruit trees: mangoes 100,614 rai (0.01 million rai), or 0.49 percent and the rest meadow and animal shelters 98,869 rai (0.09 million rai), or 0.48 percent, aquaculture establishments 87,114 rai (0.08 million rai), or 0.43 percent, other agricultural areas 53,124 rai (0.05 million rai), or 0.26 percent, respectively. The details of each type of agricultural areas scattered in different provinces in the Chi River Basin are shown in **Appendix B.4**: Strategic Environmental Assessment Report.

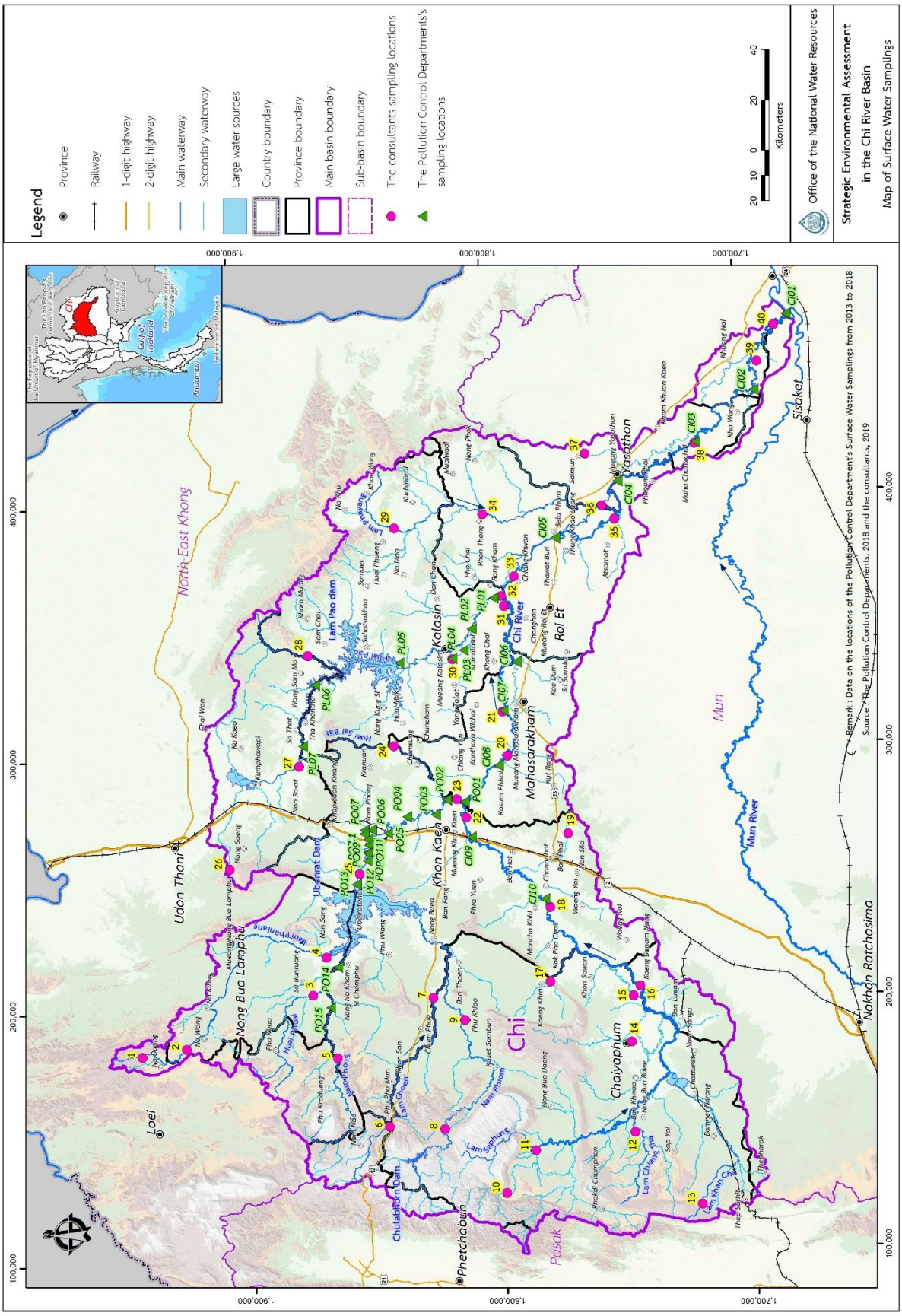
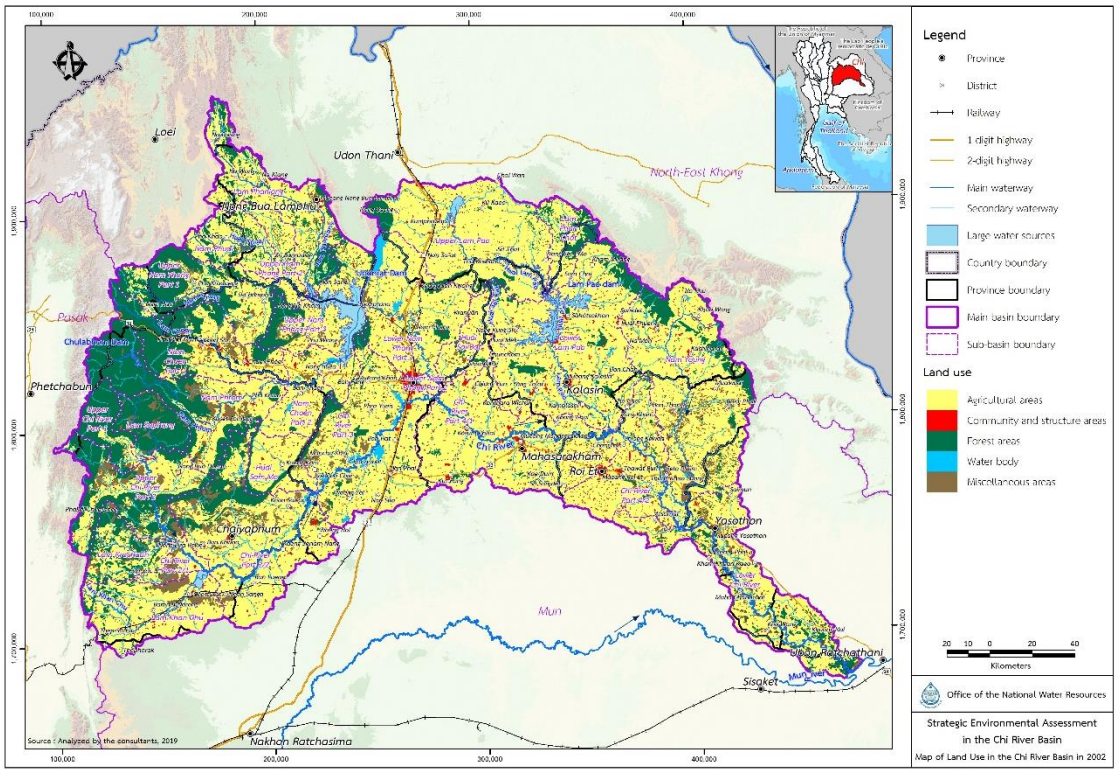
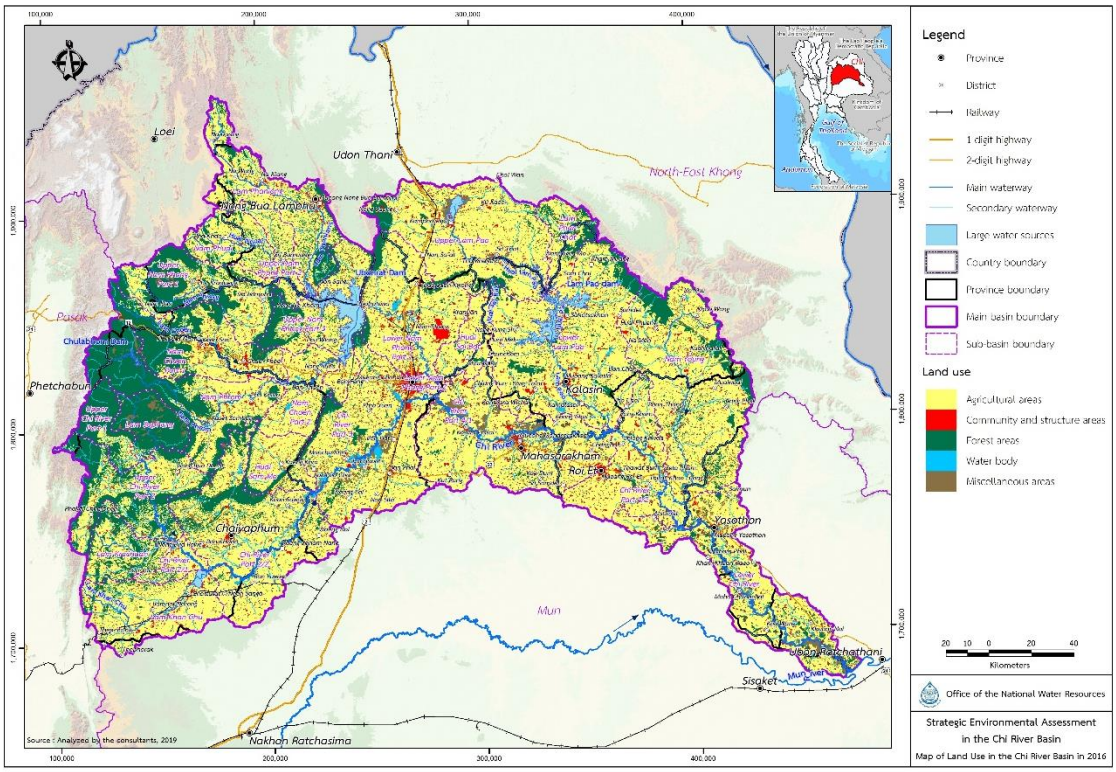


Figure 3.1-6 Locations of the Pollution Control Department's Surface Water Samplings and Project Surface Water Samplings



Land Use in the Chi River Basin in 2002



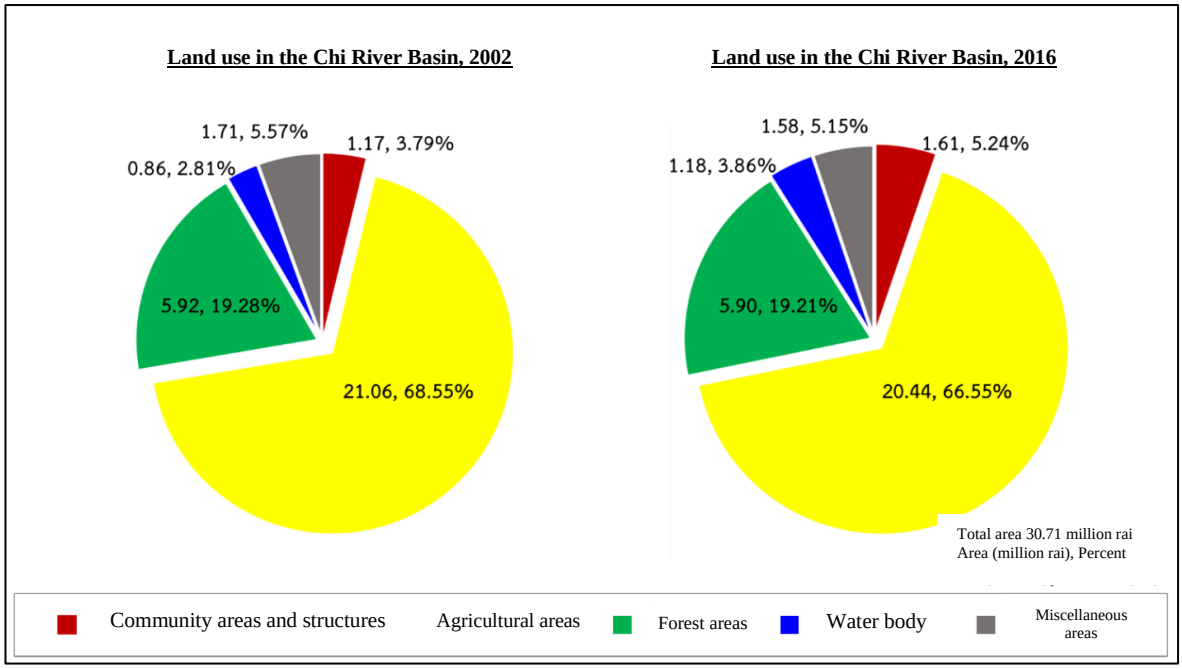
Land Use in the Chi River Basin in 2016

Figure 3.1-7 Land Use in the Chi River Basin in 2002 and 2016

Table 3.1-1 Land Use Changes in the Chi River Basin

Land use type	2002		2016		Changes		Remark
	million rai	Percent	million rai	Percent	million rai	Percent	
Community areas and structures	1.17	3.79	1.61	5.24	0.44	38.03	Increased
Agricultural areas	21.06	68.55	20.44	66.55	-0.62	-2.94	Decreased
Forest areas	5.92	19.28	5.90	19.21	-0.02	-0.38	Decreased
Water body	0.86	2.81	1.18	3.86	0.32	37.33	Increased
Miscellaneous areas	1.71	5.57	1.58	5.15	-0.13	-7.66	Decreased
Total	**30.71**	**100.00**	**30.71**	**100.00**	**-**	**-**	**-**

Remark : Land use map data at provincial level, The Land Development Department, 2002 and 2016
Source : Analyzed by the consultants, 2019



Remark : Land use map data at provincial level, The Land Development Department, 2002 and 2016
Source : Analyzed by the consultants, 2019

Figure 3.1-8 Percent of Land Use in the Chi River Basin in 2002 and 2016

3.1.6 Forest Resources and Watershed Classes

1) Forest resources: The Chi River Basin area is comprised of forest areas covering 5,091,486 rai (5.09 million rai), which represent 16.58 percent of the river basin area (The Bureau of Forest Land Management, the Royal Forest Department, 2018). The local legal conservation forests consist of national parks, wildlife sanctuaries, non-hunting areas, forest parks, arboretums, and areas which are going to be declared as national parks which represent 12.70 percent of the river basin area (3,899,675 rai or 3.90 million rai), as illustrated in **Figure 3.1-4**.

2) Watershed classes – More than half of the Chi River Basin area is characterized as Watershed Class 5. That is, 57.82 percent of the area is composed of plains or lowland or slight slopes and is mostly utilized for agriculture, e.g. rice and field crop cultivation. It is identified that 25.36 percent of the area is classified as Watershed Class 4 and 3.32 percent, Watershed Class 3. As for Watershed Classes 1A, 1B, and 2, which are watershed areas, they represent 9.69, 0.85, and 2.96 percent, respectively, as shown in **Figure 3.1-10**.

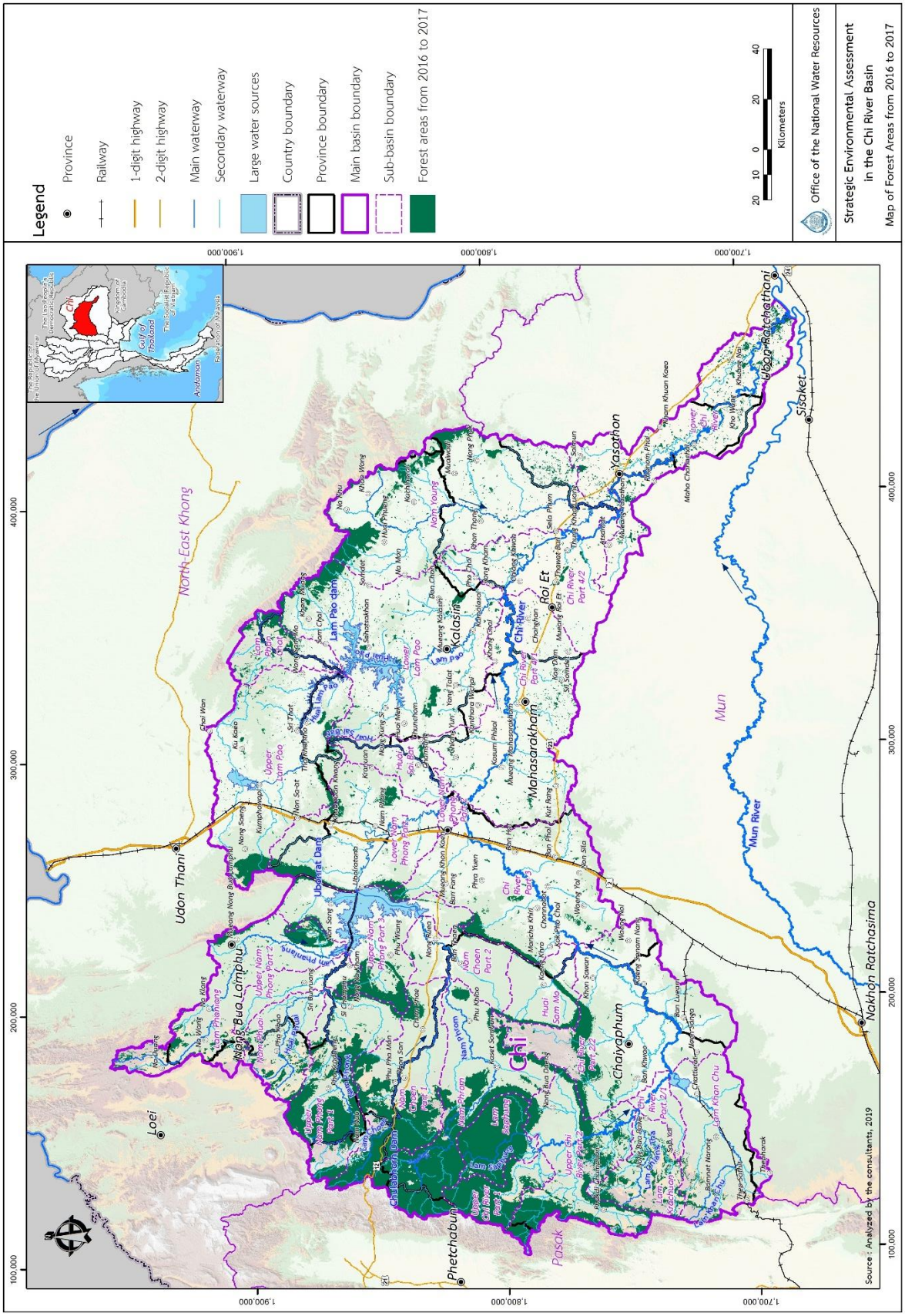


Figure 3.1-9 Forest Areas from 2016 to 2017 of the Chi River Basin

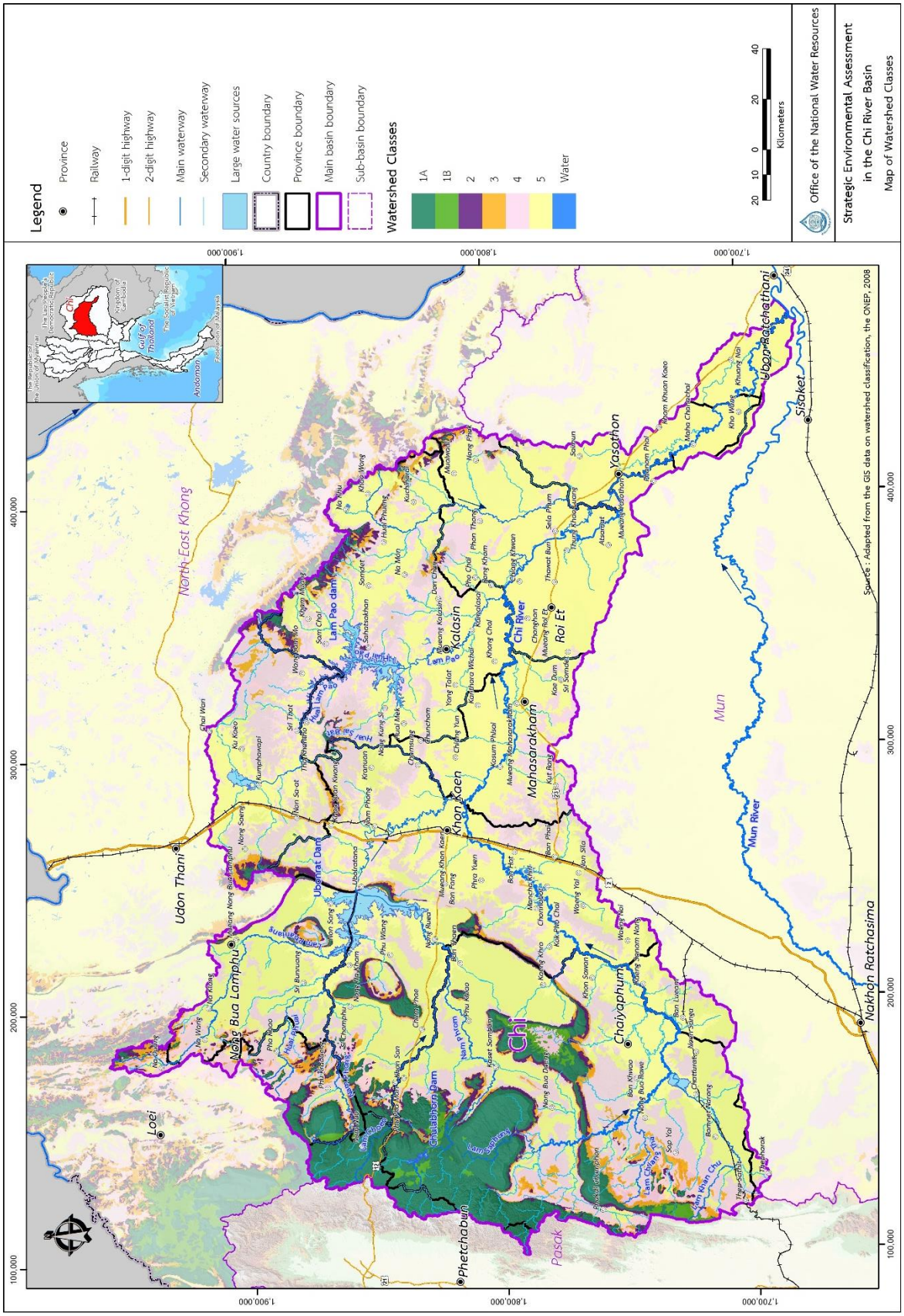


Figure 3.1-10 Watershed Classes of the Chi River Basin

3.1.7 Population, Economy and Society

The collected socio-economic data on the Chi River Basin area derived from the 2017 Village-Level Socio-Economic Database for 13 provinces, 115 districts, 811 sub-districts (sub-district administrative organizations and municipalities), and 9,220 villages, as shown in **Figure 3.1-11**, which consist of Nakhon Ratchasima, Si Sa Ket, Ubon Ratchathani, Yasothon, Chaiyaphum, Nong Bua Lam Phu, Khon Kaen, Udon Thani, Loei, Maha Sarakham, Roi Et, Kalasin, and Phetchabun, reveals that the Chi River Basin has a total population of 5,953,334 (5.95 million) and 1,842,711 (1.84 million) households. The average number of members per household is 2.87 and working-age members per household is 1.43. The agricultural areas span approximately 20,436,852 rai (20.44 million rai), mostly used for agricultural activities: rice cultivation, covering 11,729,674 rai (11.73 million rai) followed by farming 6,765,732 rai (6.76 million rai). The average agricultural household income is 89,829 baht per year.

3.2 Current Water Source Projects

3.2.1 Current Water Availability Sources

Existing completed water source projects and irrigation projects in the Chi River Basin area consist of large-, medium-, small-scale water source projects and pumping projects. The main responsible agencies consist of the Royal Irrigation Department, the Department of Water Resources and the Electricity Generating Authority of Thailand (EGAT). There are altogether 2,765 projects, with the total storage capacity of the large- and medium-scale projects of approximately 7,139.72 MCM, total irrigation areas of approximately 3,446,187 rai (3.45 million rai), and beneficiary areas of 1,154,992 rai (1.15 million rai), as summarized in **Table 3.2-1.**

Table 3.2-1 Existing Water Source Projects in the Chi River Basin

No.	Project	Number of projects	Storage capacity (MCM)	Irrigation area (rai)	Benefiting area (rai)
1.	Large-scale water source projects	6	4,758.05	818,531	-
2.	Medium-scale water source projects	150	929.21	1,033,724	24,959
3.	Small-scale water source projects	2,040	1,452.46	143,977	1,076,983
4.	Pumping projects	569	-	1,449,955	53,050
Total		**2,765**	**7,139.72**	**3,446,187**	**1,154,992**

Source : The Royal Irrigation Department, the Department of Water Resources and EGAT, 2019

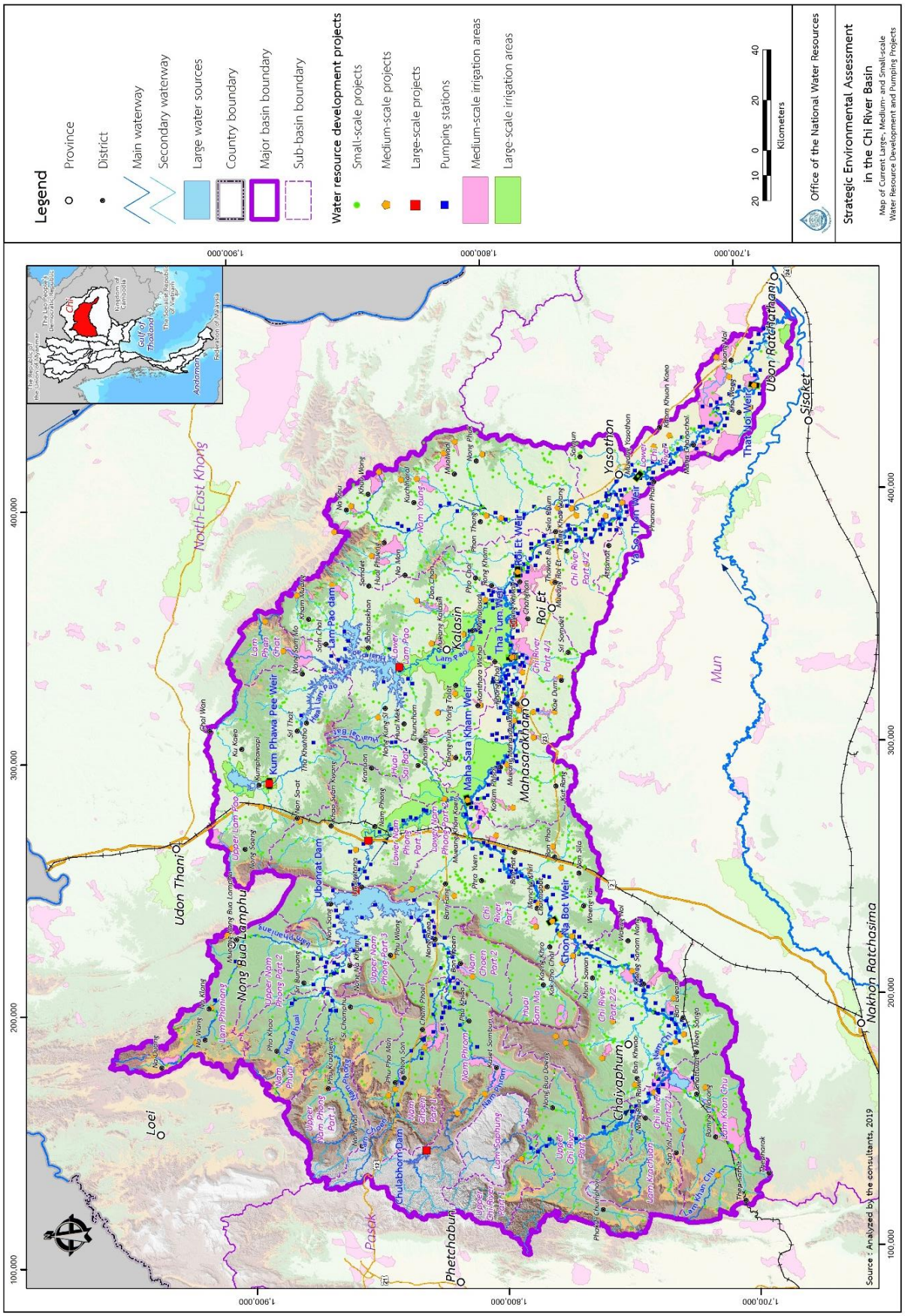


Figure 3.1-11 Provincial Population Density and Urban Communities in the Chi River Basin

3.2.2 Large and Medium-scale Irrigation Projects

The Chi River Basin has large- and medium-scale water availability sources with a total reservoir capacity exceeding 20 MCM and six weirs blocking the Chi River, with a combined capacity of 164 MCM. The 14 structures have a total capacity of 5,026.45 MCM. The remaining 142 projects have a total capacity of 660.81 MCM, as illustrated in **Figure 3.2-1**.

The Chi River Basin has water availability sources exceeding 20 MCM by only 5,026.45 MCM, with three large dams, with a combined capacity of 4,575.05 MCM but with an effective storage capacity of only 3,871.16 MCM, which results in water shortages in the river basin. The development of large- scale projects experiences constraints on the topography, which is typically flat areas, and has a lot of social and environmental impacts.

Khon Kaen has a large-scale reservoir, which is called the Ubol Ratana Dam, which has an effective storage capacity of 1,849.63 MCM. Combined with the capacity of the Nong Wai Weir and rural weirs, this makes Khon Kaen have the greatest combined reservoir capacity, which is 1,946.63 MCM. This is followed by Kalasin, which has the Lam Pao Dam, with a capacity of 1,895 MCM, and the Wang Yang Weir, with a capacity of 1,928 MCM. Chaiyaphum has the Chulabhorn Dam (with an effective storage capacity of 126.53 MCM), the Upper Lam Pathao Dam, Lam Khan Chu Dam, and Huai Kum Dam, which have a total reservoir capacity of 230.93 MCM.

3.2.3 Groundwater Development

According to the Department of Groundwater Resources' groundwater well data, in 2019, the Chi River Basin area consists of 15,423 active groundwater wells, as shown in **Figure 3.2-2**. Most groundwater wells are in Khon Kaen (3,641), followed by Chaiyaphum (3,263), and Kalasin (2,048). Their use is divided into three types: 1) Agriculture, e.g. cultivation and livestock, 2) Business, e.g. trade, service, and industry, and 3) Domestic use, as summarized in **Table 3.2-2**.

Table 3.2-2 Number of Groundwater Wells by Province and Chi Sub-basin

No.	Province	Type of groundwater wells in the Chi River Basin			Total (wells)
		Agriculture	Business	Domestic use	
1	Chaiyaphum	877	274	2,112	3,263
2	Nakhon Ratchasima	30	5	125	160
3	Phetchabun	-	-	23	23
4	Loei	20	7	277	304
5	Nong Bua Lam Phu	78	102	796	976
6	Khon Kaen	540	534	2,567	3,641
7	Maha Sarakham	131	109	1,231	1,471
8	Udon Thani	5	55	882	942
9	Kalasin	198	168	1,682	2,048
10	Roi Et	114	57	1,559	1,730
11	Yasothon	89	43	548	680
12	Si Sa Ket	5	-	28	33
13	Ubon Ratchathani	14	2	136	152
Total groundwater wells in the Chi River Basin					**15,423**

Source : The Department of Groundwater Resources, 2016

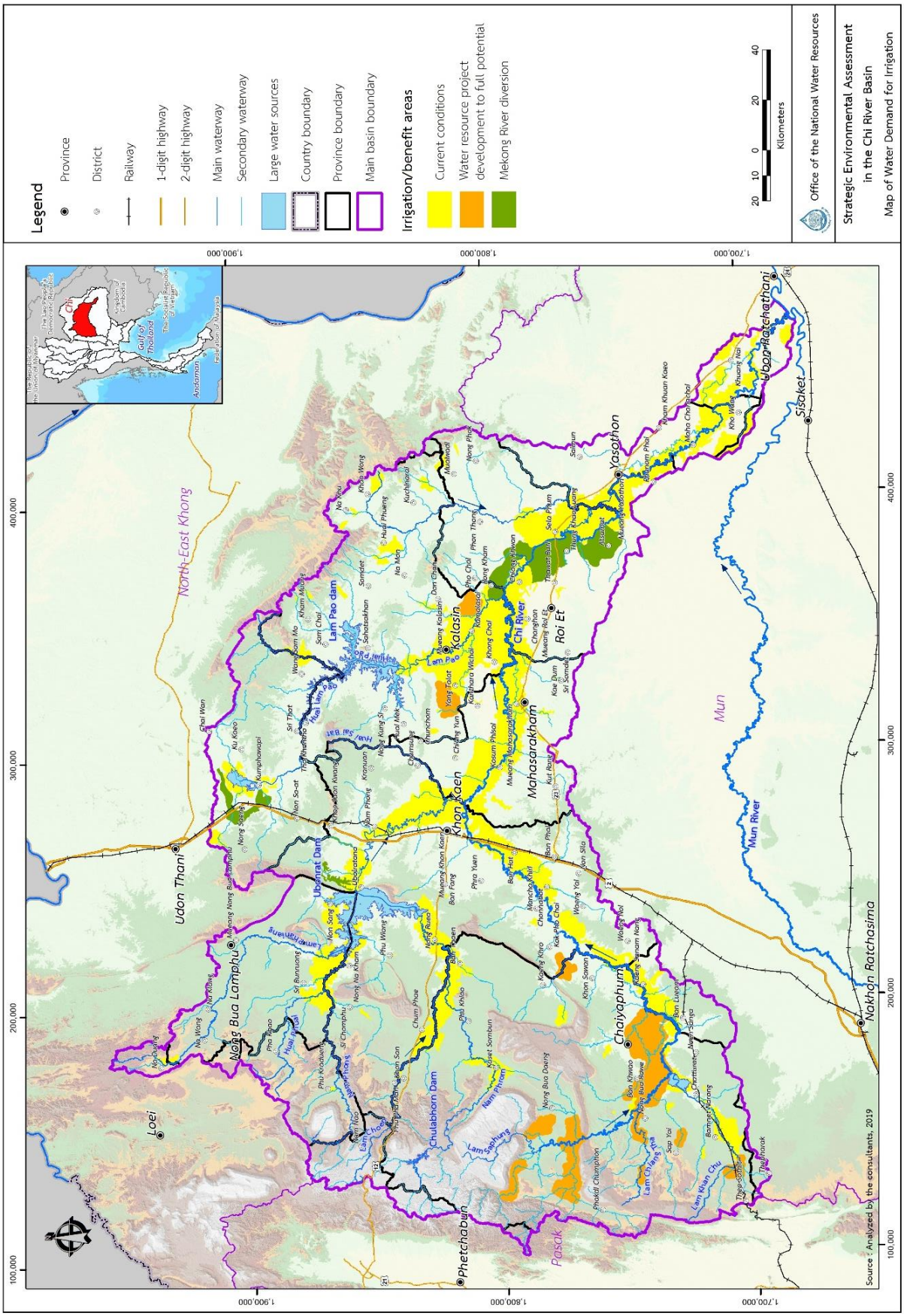


Figure 3.2-1 Existing Large- Medium- and Small-scale Water Source and Pumping Projects on the Chi River Basin

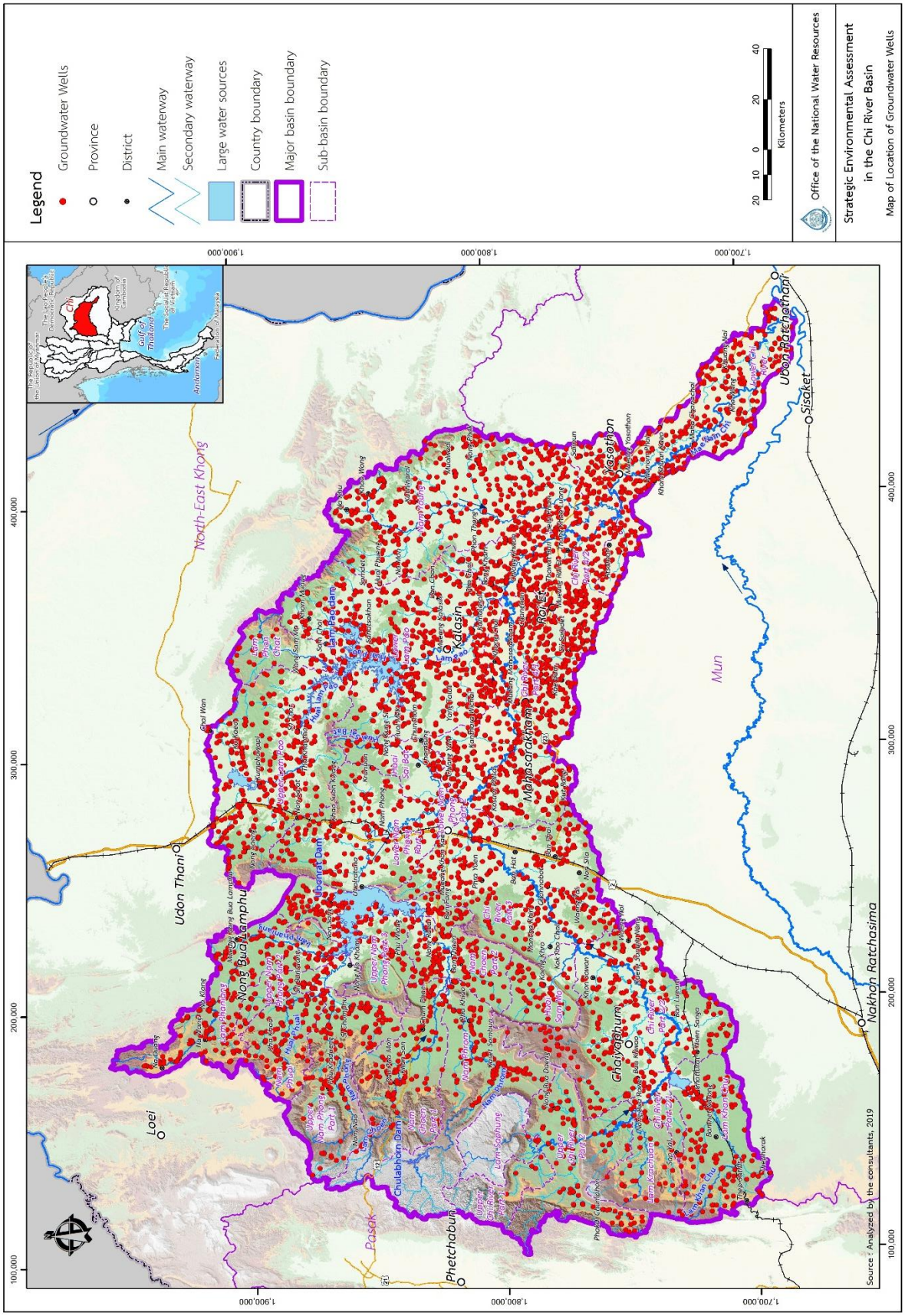


Figure 3.2-2 Locations of Groundwater Wells

3.3 Climate Change in the Future

Climate change has an impact on the world's water cycle, which is one factor that influences the change in water resources. For example, when the amount of evaporation is greater than rainfall, the amount of runoff and groundwater recharge will decrease, which will cause water shortages. Planning on the management of water resources in the Chi River Basin in the future required the study of climate change and analysis of the trends of historical change in rainfall and runoff in the study areas and change in temperature and evaporation rates. The analysis was conducted in conjunction with the results of regional model-based climate calculations for forecasting climate change which affects the amount of runoff of the Chi River Basin in the future. The results of the study on climate change in the Chi River Basin area which will have different impacts are outlined below:

1) Trends of temperature change: The study of the annual average maximum and minimum temperature revealed a significant increase. The average maximum temperature tends to a 0.1-degree Celsius increase per decade and the average minimum temperature tends to have a 0.24-degree Celsius increase per decade.

2) Trends in change in rainfall amounts – The analysis of long-term rainfall data from 23 gauging stations of the Meteorological Department showed a downward trend of the annual cumulative rainfall.

3) Based on the study of climate change in the project area in the future, the trends of change in runoff in the Chi River Basin area were analyzed to forecast potential impacts on the volumes of water availability and future water demand within the project period.

4) The results of the study on the trends of runoff change are outlined below:

- The amount of annual accumulative runoff tends to decrease.
- The amount of runoff in August tends to increase during high-water months.
- The amount of runoff in other months tends to decrease, especially in the dry season.

3.4 Population and Economic Forecast

3.4.1 Population and Tourist Forecast

1) Forecast of the population of the Chi River Basin in the next 20 years (2018-2037) – The population in the Chi River Basin in 2017 totaled 5,953,334 (5.95 million). It is forecast to reach 6,045,476 (6.04 million) in 2022 (year 5). Based on the population forecast in 2037 (year 20), the total population will be 6,386,218 (6.38 million). In 2037, provinces located in the Chi River Basin expected to have the highest population growth rate consist of Khon Kaen (1,610,245 or 1.61 million people), Chaiyaphum (1,077,555 or 1.07 million people), Kalasin (897,742 or 0.89 million people), Roi Et (855,343 or 0.85 million people), and Maha Sarakham (626,092 or 0.63 million people), respectively.

2) Tourists – Since the beginning of this year, this area has been visited by 4.27 million tourists, which is forecast to increase to 8,975,513 (8.98 million) in 20 years.

3) Industry – Currently, in the Chi River Basin, there are 16,055 factories. Based on the statistics on GPP growth, it is forecast that the annual growth of GPP in the industrial sector will be 3.4 percent.

3.4.2 Trend of Economic Development in the Next 20 Years

The trend of economic development in the next 20 years as a result of the use of economic production factors, capital, labor and others, and natural factors (water), land, fertilizer etc. is as follows:

Based on the data on the gross provincial product (GPP) of the Chi River Basin from 1995-2018, when the 7th-12th National Economic and Social Development Plans were applied, Nakhon Ratchasima had the highest economic base, followed by Khon Kaen, Ubon Ratchathani and Udon Thani, respectively and the provinces with the lowest economic base consisted of Nong Bua LamPhu, Yasothon and Maha Sarakham, respectively. From the 9th-12th National Economic and Social Development Plans, the GPP growth rate among these provinces increased. During the 12th National Economic and Social Development Plan (2017-2018), the GPP growth rate of Nakhon Ratchasima and Khon Kaen was low, which represented 1.80 and 1.15 percent, respectively. However, Nakhon Ratchasima ranked No. 2 among these 13 provinces in terms of an increase in GPP, which was 6,000 million baht (Ubon Ratchathani ranked No. 1, which enjoyed a 6,027 million baht increase in GPP). Khon Kaen enjoyed an increase of 3,100 million baht. From 2017-2018, Udon Thani had the lowest GPP increase, which was 1,575 million baht, while the GPP increase for Yasothon was 1,668 million baht and for Nong Bua Lam Phu was 2,041 million baht.

The overall gross product growth rate for the Chi River Basin (from 1996-2018) during the 8th National Economic and Social Development Plan (1997-2001) was affected by the economic crisis in 1997, when the GPP growth rate hit the bottom. During the 9th and 10th National Economic and Social Development Plans (2002-2011), the GPP growth rate significantly rose, and it declined during the 11th National Economic and Social Development Plan (2012-2016) and the 12th National Economic and Social Development Plan (2017-2018).

Given the two conditions: 1) Based on the current trend, it is forecast that the annual gross product growth rate will be only 1.80 percent; and 2) With efficient water management, it is forecast that the annual gross product growth rate will reach 3.00 percent.

3.5 Current and Next-20-Year Water Demand

Water use conditions in the current year (2019) and the future year (2037) are taken into account to be in line with the 20-year national strategic plan (2018-2037).

3.5.1 Case Study

Concerning water demand at the present time (2019) and in the next 20 years (2037) and in accordance with the 20-year national strategic plan (2018-2037) and the 20-year master plan for water resource management (2018-2037), different water use activities were analyzed, e.g. domestic use, industry and tourism, livestock, and ecosystem conservation. The consideration of current and future water use took into account the potential of agricultural areas which will be developed to be irrigation areas, industrial expansion, population increase, tourists and livestock. The case study was as follows:

1) Case 1: Water demand in current conditions (2019).
2) Case 2: Future water demand (2037) in case of the development of water source projects in the Chi River Basin at their full potential.
3) Case 3: Future water demand (2037) in case of the development of water source projects in the Chi River Basin at their full potential and the diversion of water from the Mekong River.

Water demand in the agricultural sector represents 97.00 percent. The Chi River Basin consists of agricultural areas spanning 20.44 million rai. Currently, the total irrigation areas and benefiting areas span 4.60 million rai, with rainfed agricultural areas of 15.84 million rai. In the Chi River Basin, the agricultural areas with the potential to be developed to be irrigation areas and benefiting areas cover 9.55 million rai (4.60 million rai in total).

Given the potential of the agricultural areas and water resources in the river basin, including an opportunity for diverting water from the Mekong River for use in the northeastern Mekong, Chi and Mun river basins, the analysis of water demand for irrigation is outlined below (**Figure 3.5-1)**:

1) Case 1: In the current conditions (2019) – 4.60 million rai for irrigation areas and benefiting areas.

2) Case 2: Future conditions (2037) – In case of the development of water source projects in the Chi River Basin at their full potential: 7.49 million rai for irrigation areas and benefiting areas.

3) Case 3: Future conditions (2037) – In case of the development of water source projects in the Chi River Basin at their full potential and the Mekong River diversion: 9.55 million rai for irrigation areas and benefiting areas.

3.5.2 Surface Water Demand for Different Activities

The analyzed water demand under the section is the demand for surface water in the Chi River Basin, divided into different activities, as follows:

1) Agriculture – It deals with water use by agricultural areas in irrigation areas and beneficiary areas. The increase in the areas in the future took into account the development of water source projects in the Chi River Basin at their full potential. Increasing the areas requires the increase in water availability by diverting water from the Mekong River to contribute to water use in the Chi River Basin.

2) Domestic use – It is considered based on population expansion and urban and rural rates water use rates.

3) Industry – It is considered based on the number of existing businesses, the water use rate of each industry, and industrial expansion based on the statistics of GPP contributed to by the industrial sector.

4) Tourism – It is considered based on the expansion of tourists and the water use rate for respective types of tourists.

5) Livestock – It is considered based on the expansion of livestock and the water use rate for respective types of animals.

6) Downstream ecosystem conservation – This focuses on the minimum amount of water to be discharged downstream from the large- scale reservoir. The water can be recycled, and the areas which will use the water are located downstream from the reservoir.

The results of analysis of water demand in each activity are summarized in **Table 3.5-1**.

Table 3.5-1 Analysis of Water Demand in Each Activity in Current and Future Conditions

Water use activity	Current condition (2019)		Future 20 years (2037)			
	Irrigation and benefit areas (rai)	Water demand (MCM/year)	In case of water source project development in the Chi River Basin at full potential		In case of water source project development in the Chi River Basin at full potential and Mekong River diversion	
			Irrigation and benefit areas (rai)	Water demand (MCM/year)	Irrigation and benefiting areas (rai)	Water demand (MCM/year)
1. Agriculture[1/]	4,601,179	4,899.66	7,488,559	7,822.73	9,550,315	12,193.69
2. Domestic use	-	125.67	-	129.11	-	129.11
3. Tourism	-	1.12	-	2.34	-	2.34
4. Industry	-	33.07	-	55.38	-	55.38
5. Livestock	-	9.16	-	15.92	-	15.92
Total[2/]	**4,601,179**	**5,068.67**	**7,488,559**	**8,025.48**	**9,550,315**	**12,396.44**

Remark : [1/] Water demand for agriculture : water flowing back is deducted.
[2/] Water for maintaining the ecosystem is water discharged from large-scale reservoirs, whereby water can be reused, so it is not included in the water demand.

Source : Analyzed by the consultants, 2019

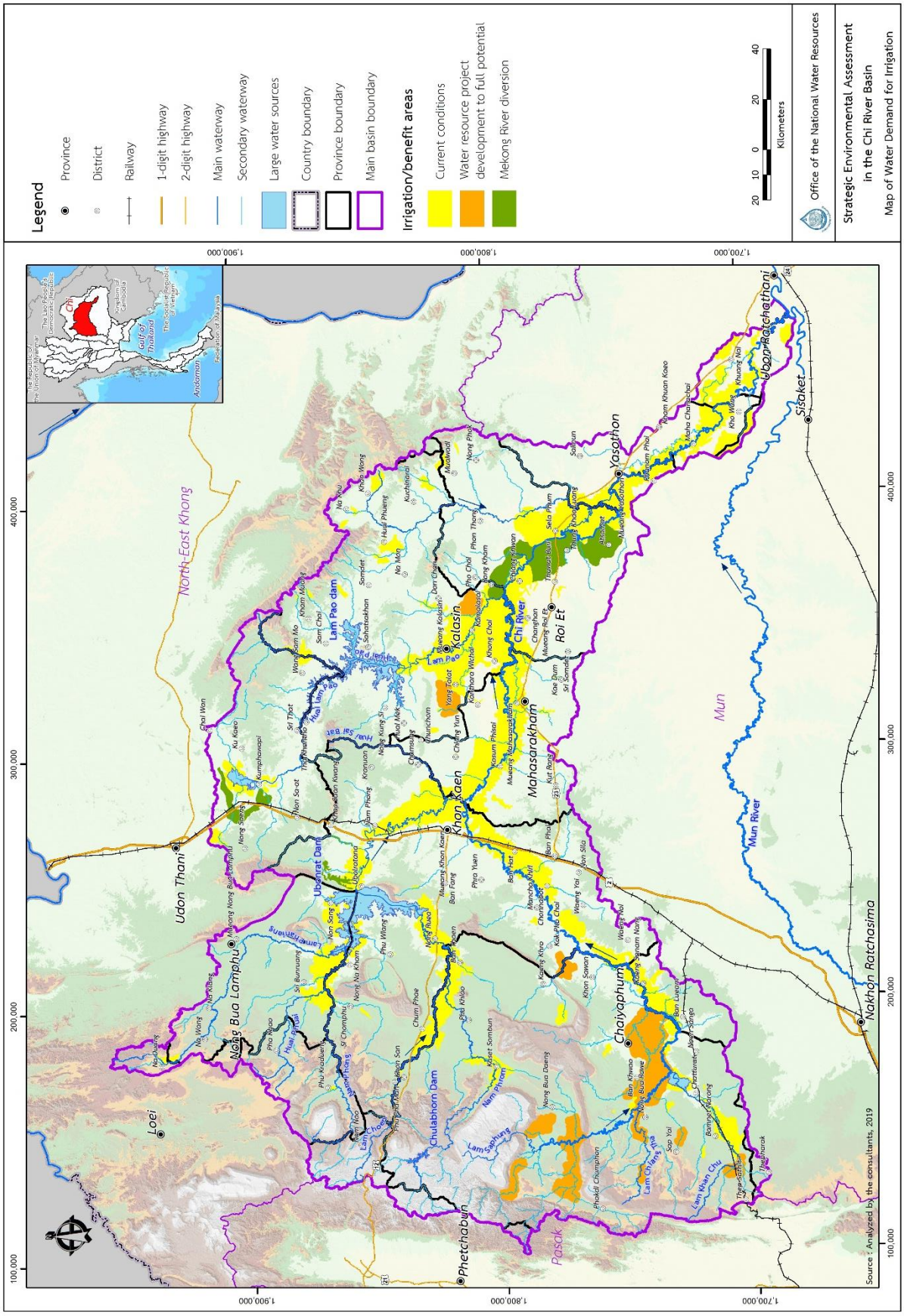


Figure 3.5-1 Current Agricultural Areas and Development Potential

3.5.3 Groundwater Demand

Based on the data on groundwater wells by the Department of Groundwater Resources in 2019, an analysis was carried out on groundwater demand. The analysis was done on the water yield rates of groundwater wells, which were calculated in conjunction with the groundwater pumping period on a daily basis. It suggested that demand for groundwater for domestic use is of the highest amount. The groundwater demand for domestic use amounts to approximately 494.11 MCM per year (44.25 percent), followed by groundwater demand for industry, which amounts to 331.70 MCM per year (29.70 percent) and groundwater demand for agriculture, 290.91 MCM per year (26.05 percent). In conclusion, the total groundwater demand for different activities amounts to 1,116.72 MCM per year.

3.6 Analysis of Water Use in the Chi River Basin

The analysis of water balance in the Chi River Basin was carried out based on the characteristics of the development of water source projects in the Chi River Basin in current conditions (2019) and in the next 20 years (2037), as follows:

Case 1: Water use in current year (2019)

Case 2: Future water use (2037) in case of the development of projects in the Chi River Basin at their full potential.

Case 3: Case 2 and increase in water availability by diverting water from the Mekong River diversion.

The results of water use analysis in the Chi River Basin the current year (2019) and future conditions (2037) are summarized as shown in **Table 3.6-1**.

Table 3.6-1 Results of Current and Future Water Use Analysis

Case	Agricultural area (rai)*	Rainfed agricultural area (rai)	Irrigation and benefiting areas (rai)	Active storage capacity of large- and medium-scale reservoirs (MCM)	Water demand (MCM)	Water shortage (MCM)		
						Jun-Nov	Dec-May	All-year-round
1. Current water use	20,423,463	15,822,284	4,601,179	4,850.78	5,068.67	79.05	449.56	528.61
2. Development of water source projects at their full potential.		12,934,904	7,488,559	6,091.80	8,025.48	699.20	905.16	1,604.36
3. Case 2 and Mekong River diversion.		10,873,148	9,550,315	6,091.80	12,396.44	Water of 5,020.87 MCM per year must be diverted.		

Remarks : * Excluding agricultural areas in Mukdahan including 23,388 rai.
Source : Analyzed by the consultants, 2019

Currently, only 4,601,179 rai (4.60 million rai) irrigated agricultural land, representing 22.53 percent of the agricultural areas, can be developed. In current conditions, the Chi River Basin has a total runoff of 11,993.63 MCM per year. The total water demand amounts to 5,068.67 MCM per year (42.26 percent of the runoff amount) with a water shortage up to 528.61 MCM per year, representing 10.43 percent of the water demand. Water demand in the Chi River Basin was analyzed and summarized as follows:

1) Currently, the rainfed agricultural areas span 15,822,284 rai (15.82 million rai), which represent 77.47 percent of the total agricultural areas, and expose them to the risk of drought as they mainly rely on rainfall, especially in the areas with an average rainfall below 1,000 mm per year along the boundary between Chaiyaphum and Khon Kaen, rain shadows in Nong Bua Lam Phu, and part of Kalasin and Maha Sarakham. Thus, it is necessary to convert the rainfed agricultural areas to irrigation areas.

2) The development of water source projects at their full potential will provide another 2,887,380 rai (2.89 million rai) for irrigation areas and benefiting areas, so they will cover 7,488,559 rai (7.49 million rai) in total, which represents 36.67 percent of total agricultural areas, with water demand of 8,025.48 MCM and a water shortage of 1,604.36 MCM. This shows that the use of water availability in the Chi River Basin has started to experience water use in the river basin and water shortages as a result of water demand accounting for 66.91 percent of the amount of runoff, so there is a need to increase water availability in the Chi River Basin.

3) The diversion of water from the Mekong River to contribute to water use in the Chi River Basin (5,100 MCM) and the development of water source projects at their full potential will increase the irrigation areas and beneficiary areas to 9,550,315 rai (9.55 million rai), which represent 46.72 percent of total agricultural areas, with total water demand of 12,396.44 MCM.

3.7 Socio-economic and Environmental Data Survey

3.7.1 Socio-economic Condition Survey

The survey of current data in the Chi River Basin in terms of economic, social and environmental aspects was carried out to collect baseline data for the SEA so that the SEA preparation can properly meet the demand of stakeholders in the area. The survey of socio-economic conditions was conducted from June 29 to July 19, 2019. A total of 1,306 samples were collected from four target groups: community leaders, agricultural groups, industrial groups and trade and service groups. They are categorized according to five study areas. The survey of primary survey is:

1) Community leaders are representatives of communities. Most are village heads (55.45 percent), who gave the following economic, social and environmental information in the Chi River Basin, and opinions towards water resource management plans:

1.1) Economic data: Major occupations of people in the Chi River Basin are farmers (76.47 percent). Key crops include rice, sugarcane and cassava. According to community leaders, there are three top economic problems, namely debts, low-price products and high production costs.

1.2) Social data

(1) Social features: According to community leaders, most people in the Chi River Basin have moderate status and good livelihood. About 70.30 percent of community leaders are of view that there is no inequality problem. However, some of them (26.73 percent) think that there is currently an income disparity in the communities.

(2) Consumption-based water: 89.10 percent of drinking water is bottled water sold at the market, while 91.09 percent of water used is the village water supply, 60.00 percent of which faces turbidity and sedimentation. Some people face the most water shortage in April, especially in the five downstream areas.

(3) Water-related disaster: In the past 10 years, 83.33 percent of the Chi River Basin areas experienced drought mostly caused by low rainfall, while 39.60 percent faced floods in some years or every 4-5 years. They were mostly caused by rainfall in consecutive days.

(4) Social problems: Currently, the Chi River Basin is facing social problems and accessibility to public utilities in addition to water resources. The overall picture is at low level. Most problems relate to all vices, drugs, lack of electricity, power outage and theft, respectively.

1.3) Environmental data: In the previous 10 years, 45.54 percent of community leaders view that forest resources in the Chi River Basin declined due to illegal logging, followed by community and trade and services expansion. In the past, natural and environmental resources were partly managed via community leaders by promoting forestation, improving rivers and canals as well as dredging canals.

2) General public: Representatives of general public include water user groups in various activities. They provided economic, social and environmental information of the Chi River Basin, as well as opinions to water resource management.

2.1) Economic data

(1) Agriculture: The surveyed agricultural samples are mostly farmers. Rainfall is currently used for agriculture (64.08 percent), followed by water supply from irrigation systems and natural water sources in case of sufficient and sustainable water management. Most of them (83.21 percent) wish to grow more rice because areas are suitable for rice farming. In case of sufficient water, more productivity can be increased.

(2) Industry: Most of industrial representatives include rice mill business, 17.05 percent of which faces water shortage in April. Most of samples in the industrial sector do not have their business expansion plans in the future. Only 4 percent wish to expand their business if water is managed sufficiently and sustainably.

(3) Trade and services: Most representatives of trade and service groups use water supply with an average monthly cost of 1,713.20 baht. They usually face water shortage in April.

(4) Economic problems: After inquiring about the overall economic problem, there are currently economic problems in the Chi River Basin at moderate level in terms of lack of labor, followed by lack of farmland, unemployment and unequal income distribution.

2.2) Social problems

(1) Social characteristics: Most people in the Chi River Basin have moderate status and good standards of living. Most of them view that there is high disparity in water service accessibility (drinking water), especially between households and public agencies (average 3.81).

(2) Consumption-based water: Most people (52.27 percent) drink bottled water sold at the market and do not have such problem. About 80.83 percent use water supply and 37.24 percent experienced water quality, e.g. turbidity and sedimentation. In April, they faced water shortage.

(3) Water-related disaster: In the past 10 years, the Chi River Basin faced drought (53.78 percent). This problem takes place every year (42.28 percent). The reason for drought was because of low rainfall (40.91 percent), followed by dry spell for a long time (35.96 percent) and lack of good water use planning, e.g. reserved water in reservoirs/irrigation areas (12.28 percent). As for floods, the Chi River Basin experienced floods (22.16 percent) due to rainfall for consecutive days.

(4) Social problems: Currently, there are social and accessible public utility issues apart from water resources. The overall problem is at high level, namely alien workers, followed by inadequate schools and insufficient hospitals, respectively.

2.3) Environmental data: Over the past 10 years, general public (29.38 percent) are of opinion that forest resources in the Chi River Basin decreased because of community growth, followed by agricultural area expansion, trade and service growth, other environmental issues, such as foul, noise and wastewater issues, respectively.

3.7.2 Environmental Data Survey

The survey and collection of environmental data in project areas consist of surface water quality and groundwater quality (details are shown in **Appendix D** of Strategic Environmental Assessment Chi River Basin).

3.7.2.1 Surface Water Quality Survey and Sampling

Forty surface water quality samples were collected three times in the hot, rainy and cold seasons. The sampling locations were not duplicated with those of the Pollution Control Department. They were collected from the major streams and communities. The consulting groups specified additional sampling locations in the major streams (Chi, Phong and Lam Pao) and tributaries to be used in the study along with data measured by the department. Sampling locations are shown in **Figure 3.7-1**, as detailed in **Table D-6** in **Appendix D**.

1) 1st survey in the hot season – the assessment of water quality index indicated that most surface water quality was deteriorated (30 locations), followed by very deteriorated (seven locations) and moderate (three locations). Following the surface water quality classification pursuant to the Promotion and Conservation of National Environmental Quality Act B.E 2535 (1992), most of the water quality in the hot season was classified as surface water type 3 (14 locations), followed by type 4 (13 locations) and type 5 (13 locations).

2) 2nd survey in the rainy season – the assessment of water quality index indicated that most surface water quality was deteriorated (39 locations), followed by very deteriorated (one location). Following the surface water quality classification pursuant to the Promotion and Conservation of National Environmental Quality Act B.E 2535 (1992), most of the water quality in the hot season was classified as surface water type 3 (18 locations), followed by type 4 (17 locations) and type 5 (five locations).

3) 3rd survey in the cold season – the assessment of water quality index indicated that most surface water quality was deteriorated (35 locations), followed by very deteriorated (five locations). Following the surface water quality classification pursuant to the Promotion and Conservation of National Environmental Quality Act B.E 2535 (1992), most of the water quality in the hot season was classified as surface water type 3 (19 locations), followed by type 4 (14 locations) and type 5 (seven locations).

3.7.2.2 Groundwater Quality Survey and Sampling

Sixty groundwater quality samples were collected twice in the dry and wet seasons as detailed in **Table D-4** in **Appendix D**. The results of the first and second surveys in the dry and wet seasons, respectively indicated that the physical water quality was mostly low turbid. Water chemical properties revealed that the pH, total hardness, total dissolved solids, sulphate, nitrate and chloride met the groundwater quality standard for consumption. Most of the groundwater contained iron, manganese and arsenic met the standard groundwater quality for consumption. Agricultural pesticides, organochlorine compounds and organophosphate compounds were not found in this study. As for biological water quality, the Total Coliform Bacteria exceeded the standard groundwater quality for consumption in both seasons.

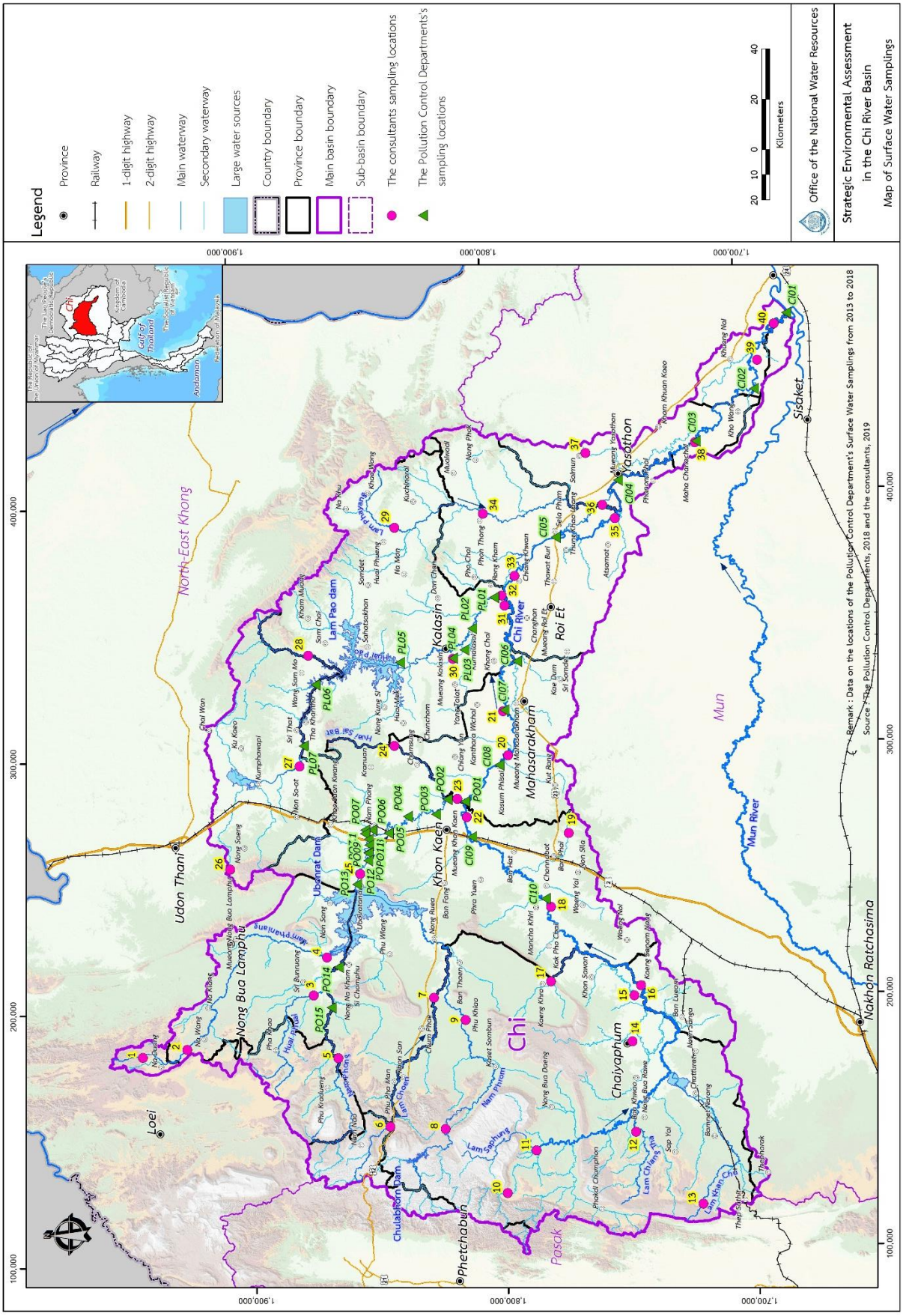


Figure 3.7-1 Locations of the Pollution Control Department's Surface Water Samplings and Project Surface Water Samplings

3.8 Problems in the Chi River Basin Area

The Chi River Basin always experiences floods, drought and wastewater. This affects livelihood and annual loss of a lot of income and assets, especially drought that usually occurs in the dry season each year. It is a socio-economic problem that leads to low-income of farmers and local people. If such problem is not solved, it will be more severe in the future. Current and future problems in the Chi River Basin are summarized as follows:

3.8.1 Current Problems in the Chi River Basin Area

Currently, the Chi River Basin area experiences drought, flooding, wastewater and encroached watershed forests. Such problems affect the environment and socio-economy, as follows:

1) Drought: The causes of drought in the local area consist of low rainfall, inadequate runoff, large agricultural areas, the fact that most areas are in low rainfall areas, highland areas, saline soil, etc.

2) Flooding: This problem results from the fact that the Chi River has very meandering streams, drainage issues, a limited capacity of the Chi River and its tributaries as a result of narrow streams, and shallow streams as a result of sediment deposition due to erosion, an inadequate number of water storages, obstacles in the streams, and obstacles along the waterways.

3) The wastewater from communities along the Chi River, agriculture, factories, and caged fish culture highly concentrated in some areas of the Chi River.

4) Watershed forests are encroached upon to be developed as tourist areas in Phetchabun, Loei, Khon Kaen, etc and as agricultural areas in the Chi River Basin.

The frequent occurrence affects living conditions and results in the loss of incomes and property of local people each year, especially drought, which occurs regularly during the dry season of every year. This leads to a connected socio-economic problem – local farmers and people earn an income which is below the country's averages.

3.8.2 Problems in the Chi River Basin Area in the Future

If the drought, flooding and wastewater issues for the above reasons, which are currently experienced by the Chi River Basin area are not addressed in the future, they will become more serious as a result of contributing factors in the future, as follows:

1) Climate Change

Climate change in the Chi River Basin area will have these impacts:

1.1) Climate change will have an impact on water demand for irrigation due to change in climate change-related factors.

1.2) Rainfall: The rainfall in the Chi River Basin area will tend to decrease, and the no-rainfall period will tend to be longer.

1.3) Runoff: A decreasing trend of rainfall and the change in land use as a result from expansion of urban areas and agricultural areas, and a decreasing trend of forest areas will have an impact on the amount of runoff. Particularly, runoff in the dry season will decrease, and the impact tends to be more severe.

2) Environment

In the future, the increase in the population, change in land use conditions, and business and industrial expansion will bring about more serious environmental problems in the Chi River Basin area, as follows:

2.1) A decrease in forest areas, as a result of forest encroachment for agriculture and tourism business or related activities will lead to a constant decrease in forest areas. Currently, the areas with forest conditions in the Chi River Basin span 5,091,486 rai, which represents 16.58 percent of the river basin area. However, due to forest encroachment, this tend to decrease. During the past seven years (2009-2016), each year, there was a 57,566-rai decrease in the forest areas, which will had the following impacts:

(1) A decrease in runoff in the dry season.
(2) Soil erosion.
(3) Flooding will become more serious.

2.2) Wastewater, which is mainly caused by the expansion of economic areas, community and industrials areas are the origin of an increased amount of wastewater. In addition, agricultural chemical use results in more chemical contamination into water bodies.

3) Economy

The inadequacy of water for the agricultural sector will lead to different problems, as follows:

3.1) More serious poverty in the agricultural sector.
3.2) Increase in income disparities between urban residents and rural farmers.

4) Society

The population in the Chi River Basin area in 2017 was 5,939,334 (5.95 million), which will increase to 6,386,218 (6.39 million) in 20 years, and will result in different problems, as follows:

4.1) Expansion of community areas: As they are economic areas, there are more people migrants from the rural areas, which results in a higher urban density.

4.2) Water demand: Currently, the water demand for different activities in the Chi River Basin amounts to 5,068.67 MCM. In 20 years, in case no development exists, the water demand will increase to 5,102.41 MCM, which will result in more serious water shortages and conflicts on water use among farmers and water use in different sectors.

4.3) Shortage of workers in the agricultural sector: The insufficiency of water and low productivity will result in low incomes in the agricultural sector, which are not adequate for living, and migration to urban areas.

Chapter 4

Chi River Basin Strategic Environmental Assessment (SEA)

Chapter 4
Chi River Basin Strategic Environmental Assessment (SEA)

The frequent occurrences of the issues of drought, flooding and water quality in the Chi River Basin area due to physical resource constraints have resulted in the insufficiency of water for a large number of people and agricultural areas and in the Chi River Basin. This has social impacts and results in labor migration and migration of rural people to urban areas because of low agricultural productivity and low incomes among farmers. The results of the analysis are as follows:

4.1 Division of Areas by Area Use Characteristics

The Chi River Basin area is composed of 30,706,152 rai (30.71 million rai) – 20,436,852 rai (20.44 million rai) is agricultural land, 10,199,949 rai (10.20 million rai) is drought-prone areas, and 3.29 million rai is flood-prone areas. The areas suffering from the wastewater issue consist of the Phong River, Lam Pao River, and the Middle and Lower Chi River. Topographically, the Chi River Basin area can be divided into:

The watershed areas of the Chi River Basin originate in the Phetchabun mountain ranges and the Dong Phaya Yen Forest, which are the watersheds of the Chi River Basin and the Pa Sak River Basin. Being at the upper part of the Chi River Basin, they are characterized as forests, mountains, or highland, which yield water and store water. They are composed of the Chi River watershed, located in Chaiyaphum and Nakhon Ratchasima, the Phong River watershed, in Chaiyaphum and Khon Kaen, the Phuai River watershed, in Loei, the Lam Phaniang watershed, in Nong Bua Lam Phu, as well as the Lam Pao watershed and watersheds originating in the Pha Phan mountain ranges, which are the watersheds of the Chi River Basin and the Songkhram River Basin in Udon Thani and Kalasin.

The midstream areas of the Chi River Basin are characterized as flat areas, community areas, and agricultural areas, which comprise the Phong River midstream area, the Lam Pao River midstream area, and the Yang River midstream area.

The downstream areas of the Chi River Basin are characterized as flood plain areas. They are agricultural areas which are frequently flooded. The Chi River flows and meets the Yang River before meeting the Mun River.

Due to topographical differences, in the study, the Chi River Basin area was divided into five areas. The study and collection of physical data on natural resources, water resources, land use, water-related disaster (flooding and drought), and socio-economic conditions, as illustrated in **Figure 4.1-1**. The details of each area are:

Area 1: The Chi and Phong River watershed areas – Spanning 13,108,043 rai (13.10 million rai), they are composed of 3,856,223 rai (3.86 million rai) forest areas and 7,140,090 rai (7.14 million rai) agricultural areas. Serving as natural resources conservation and rehabilitation areas, they are in five provinces, consisting of Chaiyaphum, Phetchabun, Loei, Nong Bua Lamphu, and Khon Kaen (34 districts and 242 sub-districts).

Area 2: The southwestern highland agricultural area – This is a drought-prone area. It spans 3,034,608 rai (3.03 million rai) – approximately 1,379,150 rai (1.30 million rai) has a medium to high risk of drought (4-10 times/10 years) and 2,578,925 rai (2.50 million rai) is agricultural land. It is located in four provinces: Chaiyaphum, Nakhon Ratchasima, Khon Kaen, and Maha Sarakham (23 districts and 116 sub-districts).

Area 3: Midstream economic area – It spans 6,215,012 rai (6.21 million rai), which is an important economic hub for the Chi River Basin. It is in four provinces, which consist of Khon Kaen, Maha Sarakham, Kalasin, and Roi Et (28 districts and 220 sub-districts).

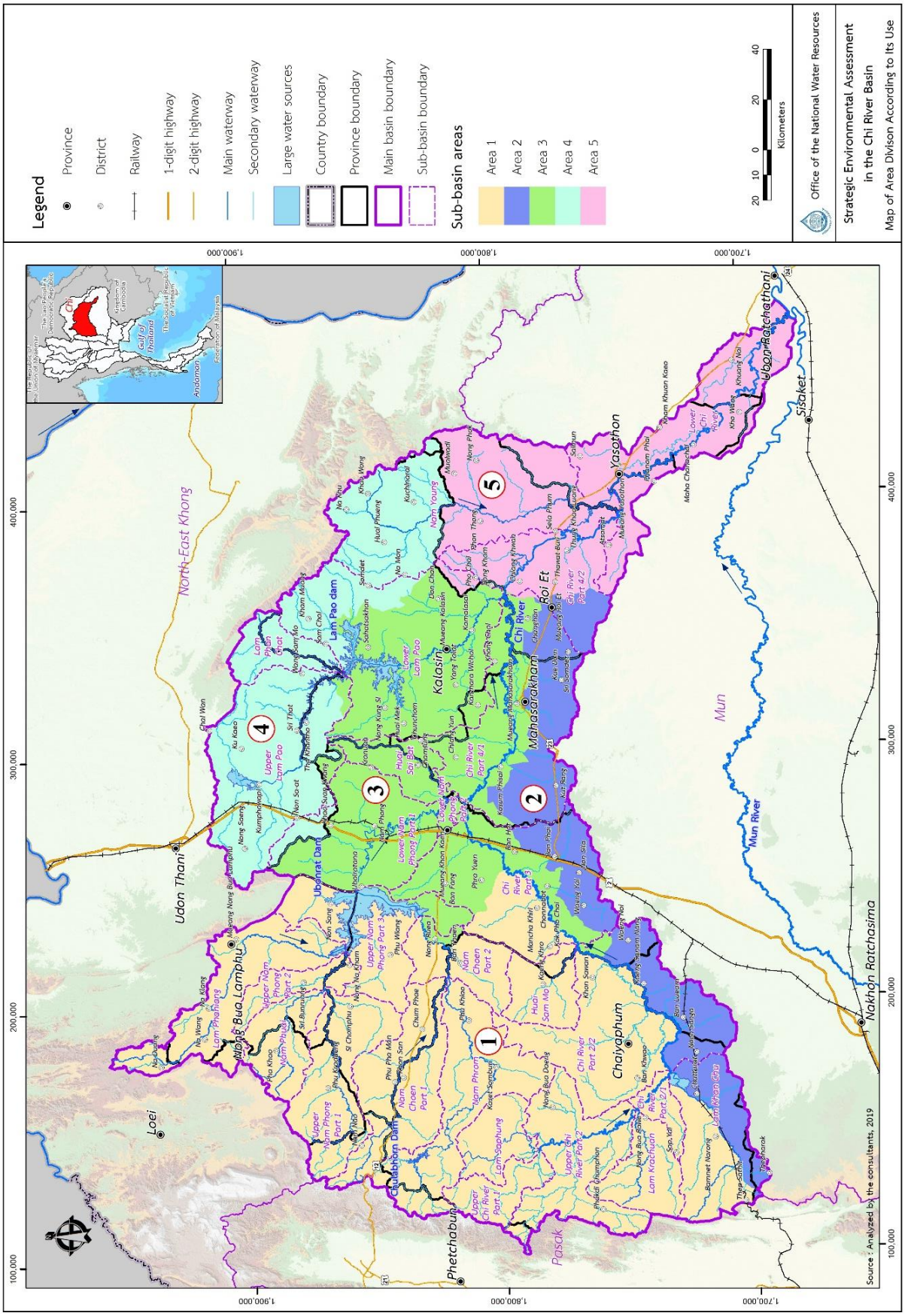


Figure 4.1-1 Area Divison According to Its Use

Area 4: The Lam Pao River watershed area – It spans 4,289,953 rai (4.29 million rai), with 3,116,237 rai (3.12 million rai) as agricultural land. It is located in two provinces – Udon Thani and Kalasin (19 districts and 104 sub-districts).

Area 5: Downstream area – It is a flood-prone area. It spans 4,058,538 rai (4.05 million rai), with 3,056,528 rai (3.13 million rai) as agricultural land and 915,607 rai (0.91 million rai) as a flood-prone area. It is in four provinces: Roi Et, Yasothon, Si Sa Ket, and Ubon Ratchathani (20 districts and 155 sub-districts).

4.2 SWOT and SOAR Analysis

4.2.1 SWOT Analysis

The Chi River Basin is located in the middle of the northeastern region, between the Mun River Basin and the Northeastern Khong River Basin. It stretches from Loei, the northernmost province in the northeastern region to Ubon Ratchathani, the southernmost province in the northeastern region of Thailand. The Chi River Basin area experiences drought and flooding almost every year. It has a total agricultural area of 20,436,852 rai (20.44 million rai), which represents 66.58 percent of the river basin area; however, there is insufficient water for agriculture, which results in farmers having a low income. There is an income disparity between urban residents and rural residents. In the location of the Chi River Basin, a water network can be developed by diverting water from the Mekong River to storages, e.g. the Ubol Ratana and the Lam Pao reservoirs, to distribute water to the Chi River Basin and Mun River Basin areas.

To develop the river basin area, local people to let access stable water thoroughly and good quality of life and to ensure sustainable development, it is necessary to conduct the strength, weakness, opportunity and threat analysis (SWOT analysis) for the Chi River Basin area. This aims to set goals in line with the river basin area conditions and measures and projects for addressing problems in the Chi River Basin in a sustainable fashion.

The SWOT analysis for the Chi River Basin area took into account internal factors in different dimensions, including environmental, social and economic dimensions for strength and weakness analysis and external factors for opportunity and threat analysis, as presented in **Table 4.2-1.**

4.2.2 SOAR Analysis

Based on the physical characteristics, land use conditions, socio-economic conditions in the five areas included in the Chi River Basin, as well as opinions from the 1st Focus Group in each of the areas:

1) The Chi River and Phong River watershed areas
2) Southwestern highland agricultural area
3) Midstream economic area
4) The Lam Pao River watershed area
5) Downstream area

The opinions of people from different areas who participated in the Focus Group were used to analyze strengths in different dimensions, including environmental and socio-economic dimensions, opportunities, aspirations, and results.

Table 4.2-1 SWOT Analysis in the Chi River Basin Area

S Strengths	W Weaknesses
1. The location of the Chi River Basin is the center which links among the Northeastern Khong River Basin, the Mun River Basin, and the Mekong Subregion. It is tending to have economic growth in the future. 2. It consists of agricultural areas, which represent 66.56 percent of the river basin area, which can be used to cultivate energy crops. 3. It is where the best-quality jasmine rice of Thailand is cultivated. 4. It comprises agricultural areas with the potential to be developed to be irrigation areas. More water availability will allow for in the increase in agricultural products. 5. It comprises a lot of natural water bodies and lowland floodplain forests scattered around in different areas. 6. There are many upper basin areas where medium-scale reservoirs can be developed. 7. Double-track railways high speed trains and road networks linking neighboring countries are developed.	1. Its average rainfall is 1,188 mm, which is lower than the national averages. Thus, there is an insufficient amount of runoff and is insufficient number of water storages for agriculture. 2. The watershed forests that are conservation forests represent only 16.58 percent of the river basin area, which is a low proportion. Encroachment into watershed forests, natural water bodies, and lowland floodplain forests, for example, have been found. 3. The local soils have no fertility and are sand soils with no water holding capacity. Some areas comprise saline soils, so land cannot be fully used. 4. The Chi River has very meandering streams and experiences a high level of bank erosion. There is a huge difference is the stream widths, which cause different areas to be flooded. 5. The irrigation system covers only 10 percent of total agricultural areas, and most local farmers carry out rainfed production. 6. The average household income is lower than the country's average. Farmers earn a low income. 7. Due to increasing population in the river basin, water must be provided to develop agriculture, including increasing community wastewater problems.
O Opportunity (SWOT)	**T Threat**
1. Water from the Mekong River can be diverted into the Ubol Ratana and Lam Pao reservoirs and different water bodies to achieve water use stability and expand irrigation areas in rainfed agricultural areas. 2. Currently, there is a high market demand for jasmine rice and energy crops, whose major production source is the Chi River Basin. 3. The construction of large- scale infrastructure which links the country's major economic areas to the region, e.g. the double-track rail network, high-speed rails, and intercity motorways reduces transport costs and allows for the development of new economic areas along the transport route. 4 The global trends which attach great importance to health care and the aging population structure result in an increase in the demand for health-related products and services, e. g. organic foods and herbs, which the Chi River Basin is ready to produce. 5. The 20-year national strategic plan and Thailand 4.0 plan will create more jobs in the city. Rural labour is likely to move to cities and agricultural machines will replace labour. There will be more aging people in the agricultural labour sector. 6. As Khon Kaen is the center of medical hub industry, it is likely that neighboring countries will use the service. 7. Transport connection will result in moving local products to neighboring countries and China. On the contrary, products from China will move to Thailand passing neighboring countries more conveniently.	1. Climate change results in more serious drought and flooding, which have an impact on agricultural production and farmer income. 2. Competition in agriculture products from neighboring countries, e.g. Vietnam, Lao PDR and China. 3. High agricultural production costs and low productivity result in the loss of competitive opportunities. 4. Lack of promotion of the use of modern technology for crop cultivation and agricultural product processing and lack of network linkages between farmer groups and agricultural markets.

Source: Analyzed by the consultants, 2019

Based on the results of the SWOT analysis for the Chi River Basin area and public hearings in which people from different areas participated in relation to the potential and strengths of respective areas, as well as local community's and people's readiness to take actions in environmental and socio-economic terms, the SOAR analysis was conducted and the results are presented in **Table 4.2-2**, for respective areas.

4.2.3 Summary of the SWOT and SOAR Analysis

The results of the SWOT analysis for the overall Chi River Basin and the SOAR analysis on respective areas are outlined below:

1) The watershed forests account for only 16.58 percent of the river basin area. Conservation and rehabilitation should be carried out for the watershed forests and agricultural land reform areas to grow economic forests to increase the size of forest areas.

2) The Chi River Basin has large agricultural areas but has the drought problem and an inadequate amount of water for agriculture. Thus, there should be development of small- and medium-scale reservoirs, rehabilitation of natural water bodies, and diversion of water from the Mekong River to increase water and create water stability and security for the Chi River Basin area.

3) The downstream area of the Chi River Basin is used for cultivating high-quality jasmine rice, for which sufficient water should be supplied.

4) The midstream economic area is ready for economic development which can link with other countries in the Mekong Subregion, and it is a major area for economic crop cultivation in the river basin.

5) People and farmers from different areas in the Chi River Basin should gather for economic value-added community products and agricultural production.

6) The agricultural area to the west of the Chi River Basin is highland which experiences aridity and water shortage. Water should be supplied by rehabilitating small-scale water bodies, distributing water body development, and developing groundwater sources for cultivation to increase incomes and upgrade the quality of life of farmers.

7) The issue of bank erosion, which causes flooding and bank erosion and has an impact on assets and living conditions of local people, should be addressed.

8) The issue of wastewater from factories, community areas, and agricultural areas should be addressed.

9) There is an income disparity between people in urban areas and those in rainfed agricultural areas, to which water should be supplied for crop cultivation to increase farmer income.

4.3 Goals and Alternatives for the River Basin Area Development

The Strategic Environmental Assessment (SEA) for the river basin area involved brainstorming among people from different provinces situated in the river basin area and analysis of problems and their solutions. In addition, goals and alternatives for the development of the Chi River Basin area were set to allow the Chi River Basin area to enjoy security, prosperity, and sustainability and balance in three dimensions: the economic, social and environmental dimensions. The goals and alternatives for the development of the river basin area are as follows:

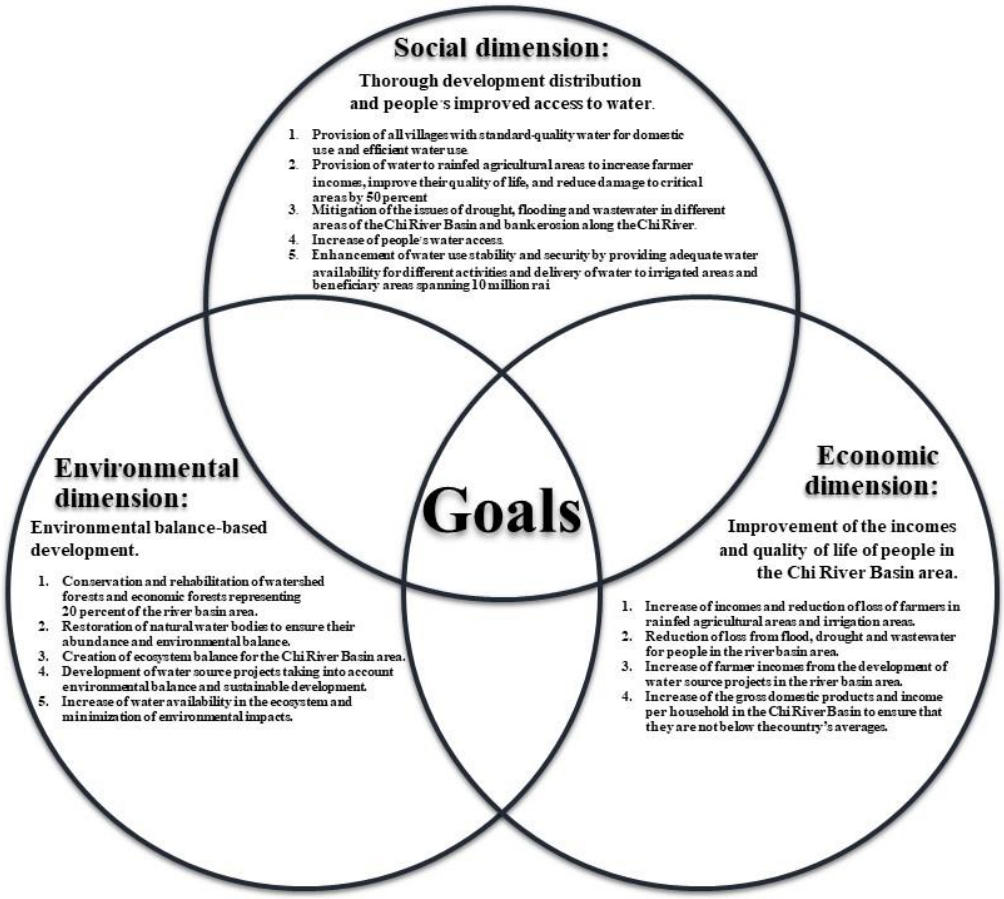
Table 4.2-2 SOAR Analysis in Different Areas in the Chi River Basin

No.	Issues of analysis	Areas				
		1. The Chi and Phong River watershed areas	2. The southwestern highland agricultural area	3. The western highland agricultural area	4. The Lam Pao River watershed area	5. Downstream area
1	Strengths					
	1) Environment	1.1) Being a watershed forest, conservation forest, and has an area suitable for reservoir construction. 1.2) Comprising riverside agricultural plains. 1.3) Comprising various famous natural tourist attractions, e.g. Phu Khiao National Park, the Hin Ngam Forest, the Tat Ton Waterfall Phu Kradueng, the Kahng Khao Cave, Phu Khing, and the Kaew Cave. 1.4) Having religious tourist attractions, e.g. Phra That Kut Chok.	1.1) Being an agricultural area for cultivating energy crops. 1.2) Being an agricultural area that can be developed well If there is sufficient water for cultivation.	1.1) Being the river basin's economic area and comprising a large communality area. 1.2) Being a large plain with irrigation systems and important cultivation areas of the Chi River Basin. 1.3) Being where different economic crops are cultivated, e.g. rice varieties, mango, lemon, rambutan, durian, date, and barometer earthstar.	1.1) Being a watershed forest area. 1.2) Being a large agricultural flat area. 1.3) Having traditional conservation tourist attractions and festivals, e.g. Wat Sinakhararam, Phrachao Tanchai, cultural events, Phu Thai Tribe Tradition, Water Festival, and Phrathat.	1.1) Having perfect-condition forests in the Yang upstream area. 1.2) Being a low plain area suitable for agriculture. 1.3) Being where high-good quality jasmine rice is cultivated. 1.4) Comprising famous tourist attractions, e.g. Ancient Fish Fossils, Phu Nam Chan, Bueang Kluea Reservoir, Wat Phraphutthabat, Don Phra That Ancient Site, and Phra That Kong Khao Noi.
	2) Society	2.1) Integration of communities and farmers.	2.1) Farmers are ready to grow crops If there is water for agriculture.	2.1) Integration of farmers, e.g. the Organic Mango Farmer Group, the Sufficiency Economy Promotion Group, the Ready-to-Drink Lemonade Promotion Group, and the Shallot Cultivation Promotion Group. 2.2) Integration of community people with different occupations, e.g. the Reed Mat Weaving Group, and the Carved Naga-shape Harp Head Promotion Group.	2.1) Existence of different occupational groups, e.g. the Reed Mat Weaving Group, Palm Sugar Group, and Rice Farming Community Enterprise, and OTOP Group.	2.1) Integration of fabric weaving groups (silk, hand-woven cotton, and indigo-dyed cotton fabric). 2.2) OTOP Product Groups, e.g. groups which make reed mats, Thai desserts, plastic baskets, and processed foods, e.g. crickets, herbs, chili paste, and catfish chili paste. 2.3) Having unique traditions and cultures, e.g. Boat Racing, Rocket Festival, Klong Tum Dance, Malai Procession, and Khao Tok (popped rice).
	3) Economy	3.1) Agricultural products, e.g. rice berry, Thap Thim Chum Phae rice varieties, sweet tamarind, and durian. 3.2) Famous subdistrict products, e.g. pickled fish, para rubber products, Ban Khwao silk fabric, Ban Non Salao khit fabric, OTOP products, and grass brooms.	3.1) Agricultural areas in the west are plateaus with field crops, sweet potatoes and sugarcane, which will be upstream products industry of agricultural and biotechnology in the future	3.1) Agricultural products, e.g. organic rice, organic salad, yam bean, corn which can be eaten raw, pickled fish, and fermented fish. 3.2) Processed products, e.g. pork jerky, sticky rice in bamboo, plastic woven baskets, and silk fabric.	3.1) Processed agricultural products, e.g. palm sugar, OTOP products, and processed agricultural products.	3.1) Woven silk and cotton fabrics. 3.2) OTOP products and processed agricultural food. 3.3) High-quality and high-price jasmine rice.
2	Opportunity	2.1) An increase in reforestation areas in conservation forests and agricultural land reform areas. 2.2) Being suitable for the construction of a reservoir which stores water for agriculture, domestic use, industry, and tourism. 2.3) An increase in incomes for local communities and people.	2.1) The provision of water by diverting water from the Mekong River to develop rainfed agricultural areas to be irrigation areas. 2.2) An improvement in productivity of energy crops and economic crops.	2.1) Expansion irrigated agricultural areas, low plain along the Chi River, and agricultural plain areas when water availability increases. 2.2) Expansion of low water use and high-price economic crop cultivation areas. 2.3) Expansion of urban communities and industries in different economic areas.	2.1) An increase in reforestation areas in conservation forests and agricultural land reform areas. 2.2) Expansion of rainfed agricultural areas to irrigated agricultural areas. 2.3) Expansion of irrigated agricultural areas to extract water from the Huai Laung Regulator Project, which diverts water from the Mekong River, as a low investment. 2.4) Shifting from rice into low water use economic crops.	2.1) An increase in reforestation areas in conservation forests and agricultural land reform areas. 2.2) Jasmine rice cultivation promotion. 2.3) Tourism promotion. 2.4) Expansion of markets for community agricultural products.
3	Aspiration	3.1) An increase in ecosystem integrity, water amounts in the dry season, and flood slow down. 3.2) An increase in water availability in the Chi River Basin. 3.3) More incomes of local people from agricultural products, community products, and tourism.	3.1) Water for agriculture.	3.1) Provision of sufficient water for economic development and irrigation area expansion. 3.2) Shifting from rice to low water use and high-price economic crops. 3.3) An increase in productivity and decrease in agricultural cost.	3.1) An increase in ecosystem integrity, increased amounts of water in the dry season, and flood slow down. 3.2) Development of irrigation areas along the Mekong River diversion route. 3.3) An increase in agricultural products.	3.1) Shifting to, and increase in, the areas for jasmine rice cultivation. 3.2) An increase in products and reduction in agricultural costs.
4	Results	4.1) Contributing to a 20-percent increase in forest areas of the river basin area. 4.2) Providing stability and security of water use for agriculture and different activities. 4.3) Providing local farmers and people with more income and good good quality of life.	4.1) Providing farmers with increased income and good quality of life.	4.1) Generating more income in the economic area. 4.2) Being the center which links to the Mun River Basin, Northeastern Khong River Basin, and GMS countries to develop the economy in the river basin area and increase local income. 4.3) Providing farmers with secure income and good quality of life.	4.1) Contributing to a 20-percent increase in forest areas in the river basin. 4.2) Providing water use stability and security. 4.3) Providing local people with more income and good good quality of life.	4.1) Providing farmers with more incomes. 4.2) Providing more incomes for different occupational groups.

Source : Analyzed by the consultants, 2019

4.3.1 Goals

The Chi River Basin area is composed of 30,706,152 rai (30.71 million rai) – 20,436,852 rai (20.44 million rai) is agricultural land, 10,199,949 rai (10.20 million rai) is drought-prone areas, and 3,294,267 rai (3.29 million rai) is flood-prone areas. The areas experiencing from the wastewater issue consist of the Phong River, Lam Pao River, and the Middle and Lower Chi River, as illustrated in **Figure 4.3-1.** In addition, it experiences the issues of water for domestic use, bank erosion, watershed forest encroachment, and natural water body encroachment. The local average income is lower than the country's averages. Based on the conditions of the problems, a study was conducted to formulate the plan on the development of the Chi River Basin area with the objectives to mitigate the drought, flooding and wastewater issues, upgrade the quality of life of farmers and people in the Chi River Basin area, to provide them with a higher income, and to develop the local economy to ensure its security, prosperity, and sustainability. The goals of the development of the Chi River Basin area in the economic, social and environmental dimensions are illustrated in **Figure 4.3-2**, as below:



Source : Analyzed by the consultants, 2019

Figure 4.3-2 Goals of the Development of the Chi River Basin Area

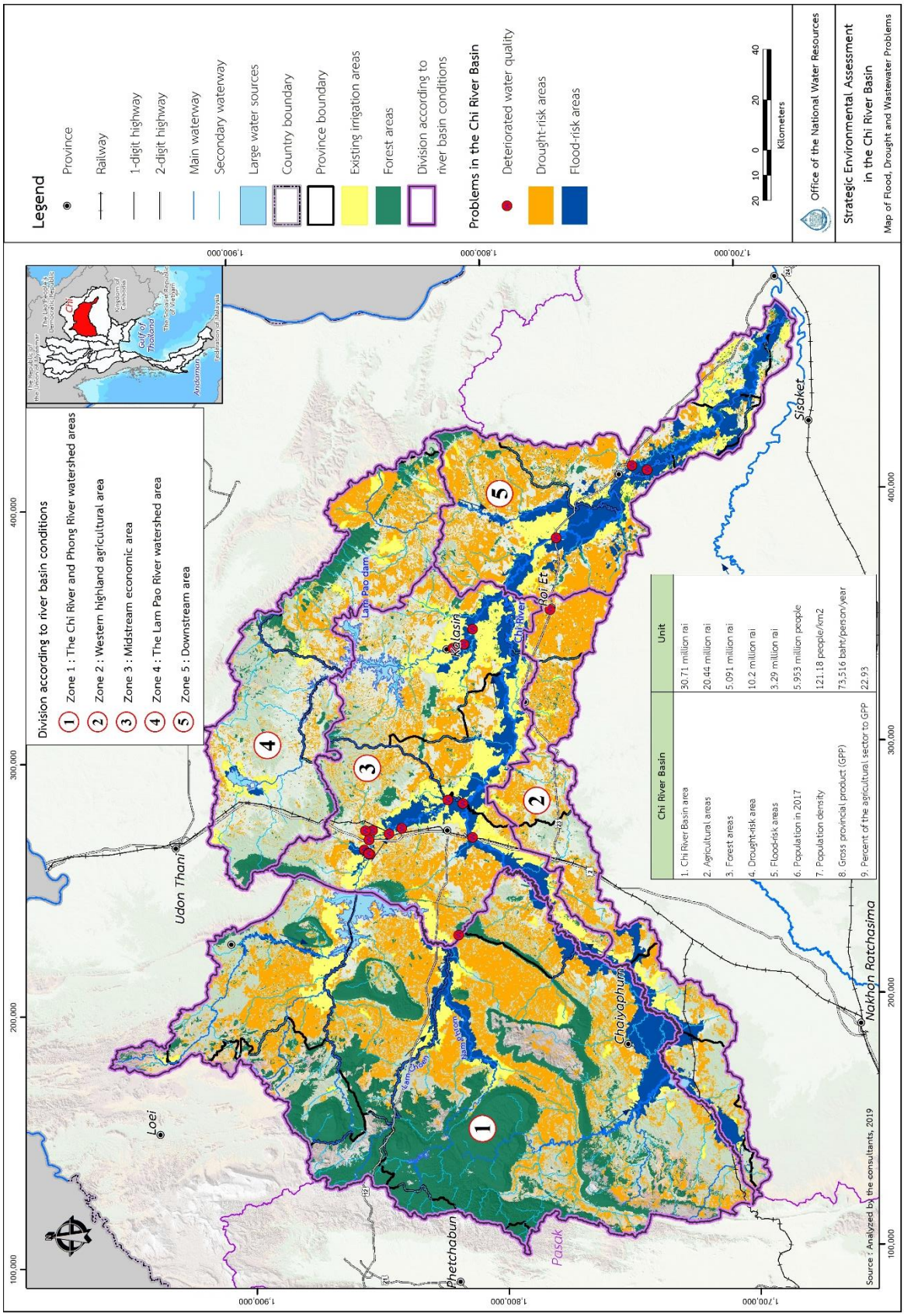


Figure 4.3-1 Flood, Drought and Wastewater Problems in the Chi River Basin Areas

1) Social dimension: Thorough development distribution and people's improved access to water.

1.1) Provision of all villages with standard-quality water for domestic use and efficient water use.

1.2) Provision of water to rainfed agricultural areas to increase farmer incomes, improve their quality of life, and reduce damage to critical areas by 50.00 percent.

1.3) Mitigation of the issues of drought, flooding and wastewater in different areas of the Chi River Basin and bank erosion along the Chi River.

2) Environmental dimension – Environmental balance-based development.

2.1) Conservation and rehabilitation of watershed forests and economic forests representing 20 percent of the river basin area and restoration of natural water bodies to ensure their abundance, ecosystem balance for the Chi River Basin area, and maximum benefits from utilizing water from water bodies.

2.2) Development of water source projects taking into account environmental balance and sustainable development.

3) Economic dimension – Improvement of the incomes and quality of life of people in the Chi River Basin area.

3.1) Enhancement of water use stability and security by providing adequate water availability for different activities and delivery of water to irrigated areas and beneficiary areas spanning 10 million rai.

3.2) Increase of the gross domestic products and income per household in the Chi River Basin to ensure that they are not below the country's averages.

4.3.2 Alternatives for the Development of the River Basin Area

Addressing the drought, flooding and water quality issues in the Chi River Basin area requires systematic planning on the development and integration among responsible agencies. The five alternatives for the Chi River Basin development to address the issues and develop the local economy were proposed, as follows:

Alternative 1: Business as usual – It is an alternative with no implementation of policy recommendations, plans or programs or no actions which are deviant from existing directions or guidelines.

Alternative 2: The development for basic necessities and development of sustainable agricultural areas – Supplying high-standard quality water for domestic use for living of local people; providing sufficient water bodies in rainfed agricultural areas to ensure self-dependence, conserving soils and rehabilitating watershed forests, reducing poverty in rural areas, and develop the Sufficiency Agriculture Model or the Khok Nong Na Model.

Alternative 3: The management of water resource-related risks at the area level and the development of related agricultural industries – Processing and adding the value to agricultural products, organic farming, and provision of water to support existing industries. This alternative aims to address the issues of drought, flood and wastewater, especially protection of floods in main cities to reduce the income gap between rural and urban people.

Alternative 4: The development of agroindustry in the northeast region – This focuses on water resource development at its full potential and provision of water to support new industries and tourism (ecotourism and prehistoric tourism). This alternative aims to increase the incomes of people in the river basin, reducing social inequality, and increase the GRP of the northeast region.

Alternative 5: **The development of business agriculture as the center of the Greater Mekong Subregion** – This alternative involves the diversion of water from the Mekong River to increase irrigated agricultural areas to respond to the expansion of all types of industries, create the stability and security of water for agriculture, especially in the dry season, and add the value of water in production (business agriculture and exportation), and increase the country's GDP.

The comparison of these individual alternatives involved the analysis of outcomes, benefits, as well as positive and negative impacts, as detailed in **Table 4.3-1**, as outlined below:

1) Results: The results of the alternatives were considered in relation to solving the basic problems, environmental management, mitigation of drought and flooding, the development of water source projects in the river basin, and the Mekong River diversion.

2) Benefits: An analysis was conducted on the benefits of the respective alternatives in relation to solving the problems, increase in agricultural areas, increase in farmer incomes, flooding mitigation, and development of the economy in the Chi River Basin area.

3) Positive and negative impacts: An analysis was conducted on potential economic, social, and environmental impacts of the respective alternatives.

4.4 Suggestion of Alternatives from Public Hearings

With respect to the alternatives for the Chi River Basin area development in **Item 4.3 Goals and Alternatives for the River Basin Area Development**, five alternatives were proposed at the 2nd Focus Group Meeting from 23 September to 4 October 4, 2019 to listen to stakeholders' opinions at 10 forums , as summarized in **Table 4.4-1** (by casting a ballot and counting, as well as announcing the results). Nine from 10 forums viewed that Alternative 3 should be developed. Only the 4th forum in Mueang Khon Kaen District, Khon Kaen Province, which is the midstream economic area, viewed that irrigated agricultural areas should be developed at full potential and water should be provided for industry and tourism according to Alternative 5.

Table 4.4-1 Summary of Scores of Each Alternative from Public Hearings

Unit : Number of ballots

Forum	District/province	Alernative 1	Alernative 2	Alternative 3	Alternative 4	Alternative 5	Total
1	Mueang District, Chaiyaphum Province	0	8	21	16	16	**61**
2	Kaset Sombun District, Chaiyaphum Province	0	11	30	10	18	**69**
3	Si Bun Rueang District, Nong Bua Lam Phu Province	1	9	35	20	18	**83**
4	Mueang District, Khon Kaen Province	0	0	14	10	17	**41**
5	Kumphawapi District, Udon Thani Province	1	7	41	3	11	**63**
6	Mueang District, Kalasin Province	0	3	34	12	10	**59**
7	Mueang District, Maha Sarakham Province	1	7	35	9	4	**56**
8	Mueang District, Roi Et Province	0	10	31	8	6	**55**
9	Phon Thong District, Roi Et Province	1	10	26	4	3	**44**
10	Kham Khuean Kaeo District, Yasothon Province	8	9	28	6	1	**52**
Total		**12**	**74**	**295**	**98**	**104**	**583**
Percent		**2.06**	**12.69**	**50.60**	**16.81**	**17.84**	**100.00**

Remark : Data from the second focus group meeting for 10 forums
Source : Analyzed by the consultants, 2019

From all the 10 forums, most of the participants (50.60 percent) regarded that Alternative 3 : **The management of water resource-related risks at the area level and the development of related agricultural industries** should be developed. The remaining (34.65 percent) should be developed at full potential according to Alternative 5 : **The development of business agriculture as the center of the Greater Mekong Subregion** and divert water from the Makong River to increase irrigated agricultural areas. Considering only economic development (Alternatives 4 and 5), 51.49 percent viewed that it should be developed by diverting the Mekong River to increase water availability in the Chi River Basin in accordance with Alternative 5.

Table 4.3-1 Results, Benefits, and Impacts of the Alternatives for the Development of the Chi River Basin Area

No.	Alternatives	Results	Benefits	Impacts
1.	**Alternative 1: Business as usual –** It is an alternative with no implementation of policy recommendations, plans or programs or no actions which are deviant from existing directions or guidelines.	1. Maintenance of existing projects to ensure their normal functioning. 2. Construction of small-scale projects based on normal budgets.	Little increase in benefits.	1. Environment — No impact. 2. Society — Huge income disparity. 3. Economy — Poverty and low income.
2.	**Alternative 2: The development for basic necessities and development of sustainable agricultural areas** – Providing standard quality water for domestic use for living of local people; providing sufficient water bodies in rainfed agricultural areas to ensure self-dependence, conserving soils and rehabilitating watershed forests, reducing poverty in rural areas, and develop the Sufficiency Agriculture Model or the Kho Ning Na Model.	**1. Solving basic problems** 1.1 Provision of water for domestic use. 1.2 Management of rainfed agricultural areas. 1.3 Provision of water sources in rainfed agricultural areas. **2. Environmental management** 2.1 Conservation and rehabilitation of watershed forests. 2.2 Recycling of treated used water. 2.3 Solving the wastewater problem.	1. Availability of water for domestic use for all households. 2. Promotion of crop cultivation in line with soil conditions in rainfed agricultural areas. 3. More water sources in rainfed agricultural areas. 4. Better quality of water in water bodies. 5. Increase in incomes of farmers in rainfed agricultural areas.	1. Environment 1.1 Low limited impacts. 2. Society 2.1 Availability of clean water for domestic use. 2.2 Improved quality of life of farmers in rainfed agricultural areas. 3. Economy 3.1 Increase in income among farmers in rainfed agricultural areas.
3.	**Alternative 3: The management of water resource-related risks at the area level and the development of related agricultural industries –** Processing and adding the value to agricultural products, organic farming, and provision of water to support existing industries. This alternative aims to address the issues of drought, flood and wastewater, especially protection of floods in main cities to reduce the income gap between rural and urban people.	**1. Solving basic problems** **2. Environmental management** **3. Drought and flood mitigation:** 3.1 Enhancement of the efficiency of water use in irrigation areas. 3.2 Project maintenance and optimization. 3.3 Development of small-scale water bodies and pumping projects. 3.4 Development of monkey cheeks in lowland floodplain forest areas. 3.5 Prevention of bank erosion based on local needs. 3.6 Flood protection.	1. Benefits specified in Alternative 2. 2. Increase in cultivation areas in the dry season in irrigation areas. 3. Increase in beneficiary areas for water pumping and small-scale projects. 4. Availability of water bodies for agriculture and beneficiary areas. 5. Alleviated flood issue. 6. Increase in farmer incomes.	1. Impacts specified in Alternative 2. 2. Greater environmental, social and economic impacts of Alternative 2: 2.1 Environment 2.1.1 Low impacts. 2.1.2 Positive impacts on lowland floodplain forests areas. 2.2 Society 2.2.1 Small impact of water pumping and small-scale projects on farmland. 2.2.2 Wider impacts, e.g. those on farmland and houses along the flood drainage alignment. 2.2.3 Impact on farmland invading public water bodies. 2.3 Economy 2.3.1 Some reduction in loss from flooding. 2.3.2 Increase in incomes for farmers in irrigation areas with improved efficiency. 2.3.3 Increase in the income of farmers in beneficiary areas under pumping projects and small-scale projects.
4.	**Alternative 4: The development of agroindustry in the northeast region –** This focuses on water resource development at its full potential and provision of water to support new industries and tourism (ecotourism and prehistoric tourism). This alternative aims to increase the incomes of people in the river basin, reducing social inequality, and increase the GRP of the northeast region.	**1. Solving basic problems** **2. Environmental management** **3. Drought mitigation** **4. Development of water source development projects in the river basin** 4.1 Development of medium- and large-scale water bodies. 4.2 Construction of water distribution systems. 4.3 Development of domestic water networks.	1. Benefits specified in Alternative 3. 2. Improvement in the mitigation of the issue of flooding from reservoirs. 3. Significant increase in irrigation areas. 4. Increase in farmer incomes. 5. Economic development in the Chi River Basin area at the provincial level.	1. Impacts specified in Alternative 3. 2. Greater environmental, social and economic impacts of Alternative 3: 2.1 Environment 2.1.1 Impacts of reservoir construction on forests and watershed classes. 2.1.2 Increase in water in the dry season for agriculture and ecosystem conservation. 2.2 Society 2.2.1 Impacts on housing and farmland in the headwork and reservoir areas. 2.2.2 Availability of water for farmers in the dry season. 2.3 Economy 2.3.1 Reduction in the loss from flooding. 2.3.2 Increase in income for farmers in existing and new irrigation areas.
5.	**Alternative 5: The development of business agriculture as the center of the Greater Mekong Subregion** - This alternative involves the diversion of water from the Mekong River to increase irrigated agricultural areas to respond to the expansion of all types of industries, create the stability and security of water for agriculture, especially in the dry season, and add the value of water in production (business agriculture and exportation), and increase the country's GDP.	**1. Solving basic problems** **2. Environmental management** **3. Drought and flood mitigation** **4. Development of water source development projects in water the river basin** **5. Mekong River diversion**	1. Benefits specified in Alternative 4. 2. Significant increase in irrigation areas and highland areas which are supplied water for agriculture. 3. Economic development at the river basin level. 4. Accommodation of economic expansion in the river basin and nearby river basins. 5. Enhanced water stability and security which ensure sustainable development.	1. Impacts specified in Alternative 4. 2. Greater environmental, social and economic impacts of Alternative 4: 2.1 Environment 2.1.1 Impacts on forests and watershed classes along the water diversion canals. 2.1.2 Higher volume of water in the Ubol Ratana and Lam Pao Dams and other reservoirs along the water diversion routes. 2.1.3 Increase in water for ecosystem conservation in the dry season. 2.2 Society 2.2.1 Impacts on houses and farmland along the water diversion canals. 2.2.2 Farmers have more water in the dry season. 2.2.3 Availability of water for industry and tourism. 2.3 Economy 2.3.1 Farmers earn more income in a lot of new irrigation areas and existing irrigation areas. 2.3.2 Sufficient water availability for economic development in tourism and industry in the Chi River Basin and nearby river basins.

Source : Analyzed by the consultants, 2019

Development in accordance with Alternative 3 involves the management of water resource risks at local level and development of continuous agricultural industry, processing, agricultural product value adding, organic agriculture and water supporting the existing industries. It is an alternative to solve floods, drought and wastewater, especially flood protection in major city areas to bridge the gap between rural and urban people. This can be implemented immediately and has low impacts on social and environmental dimensions. There is only small-scale water source development and the study and environmental impact assessment are not required. Measures/programs will be formulated to solve consumption-based water and maximize the use of rainfed agricultural areas. The Alternative 3 development covers the six aspects of the master plan for 20-year water resource management. However, the percent of population that can access to increasing water does not increase much. More than 75 percent of agricultural areas or 15 million rai are still rainfed agricultural areas. More than one thirds of runoff or more than 4,000 MCM will flow passing the Mekong River into the sea without any benefit. Flood and drought problems can be reduced in case of more development and storage in watershed areas.

4.5 Selection of Alternatives by Considering All Dimensions

As for the consideration of alternatives to select the optimal alternative, not only participation but factors/variables in three dimensions were considered: economic, social and environmental. The ranks and problem-solving needs were assessed through participation process. The selected alternative must result in the following results:

1) Achieve the goals specified in the Chi River Basin area development
2) Solve problems in the Chi River Basin area in an integrated manner
3) Be a project with low environmental impacts or have measures for restoring lost environment

To select the optimal alternative, sustainable development from many relevant agencies must be integrated.

4.5.1 Analysis Criteria and Factors

The analysis of problems in each area according to the benefit characteristics is based on the analysis of factors/variables to cover three dimensions, namely economic, social and environmental. Appropriate variables for selection are taken into consideration.

1) Primary variables refer to the determination of percent of social, economic and environmental weights. At the 2nd Focus Group Meeting, environmental weight amounts to 0.40, social weight 0.30 and economic weight 0.3.

2) Secondary variables comprise environmental, social and economic variables as follows:

2.1) Economic dimension consists of changing water availability, benefiting areas, GPP per capita and percent of trade industrial areas.

2.2) Social dimension comprises percent of population accessing to water, households that have an opportunity to get benefits, households that have an opportunity to be affected by drought, households that have an opportunity to be affected by floods, participation in suggesting alternatives and the number of cultural heritages and nature affected.

2.3) Environmental dimension comprises recycled water amount, affected forest areas, degraded forests that are rehabilitated, the number of water obstructions and the distance of dredged areas.

4.5.2 Result of Alternative Selection by Considering All Dimensions

The results of the analysis of primary and secondary variables using the Multi Criteria Analysis (MCA, the details are shown in Chapter 4) indicated that Alternative 5: The development of business agriculture as the center of the Greater Mekong Subregion has the highest scores. Thus, Alternative 5 was selected to solve problems and develop economy in the Chi River Basin area to be wealthy and sustainable. The development plans for Alternative 5 are summarized as follows:

1) Development for basic necessities and thorough development distribution
2) Management of the Chi River Basin area to solve floods, drought and wastewater
3) Economic development in the Chi River Basin area in relation to the Chi River Basin potential
4) Economic development by increasing water availability in the Chi River Basin for water use stability

Development according to Alternative 5: The development of business agriculture as the center of the Greater Mekong Subregion as shown in **Figure 4.5-1** involves water source development at full potential in the Chi River Basin and water diversion from the Mekong River to increase rainfed agricultural area, to meet the growth of all types of industries, to stabilize downstream water for agriculture, especially in the dry season, to increase water value for manufacturing (business agriculture, including export) and to increase the country's GDP.

4.5.3 Alternative 5 Suggested for the Chi River Basin Area Development

Following the suggestion of the five alternatives at the 10 forums of the public hearings, nine out of ten forums selected Alternative 3. Based on the assessment of social and economic impacts and the consideration of each alternative in economic, social and environmental aspects, Alternative 5: The development of business agriculture as the center of the Greater Mekong Subregion was selected in economic, social and environmental dimensions as it is a suitable alternative for developing the Chi River Basin area. Alternative 3 is an alternative to solve basic problems related to environmental management and to mitigate drought and flood risks, as well as continuous industries. Development plans in Alternative 3 are short- and medium-term plans.

Alternative 5: The development of business agriculture as the center of the Greater Mekong Subregion involves the provision of sufficient and stable water due to development of water source and water distribution systems, as well as diversion of water from the Mekong River to respond to the demand of water use in different activities and support development of business agriculture, industry, tourism, urban development and economic areas. It consists of medium- and long-term development plans. In the strategic environmental assessment, Alternative 5 was proposed to develop the Chi River Basin as the center of the Greater Mekong Subregion.

1) Alternative 5 results in economic and social development of the Chi River Basin than other alternatives as follows:

1.1) Water value per m^3 for producing wet season rice is higher than other alternatives (3,340 baht per m^3).

1.2) Gross provincial products will increase 2.15 percent, which is higher than other alternatives.

1.3) More people will be employed. This can solve employment and unemployment problems.

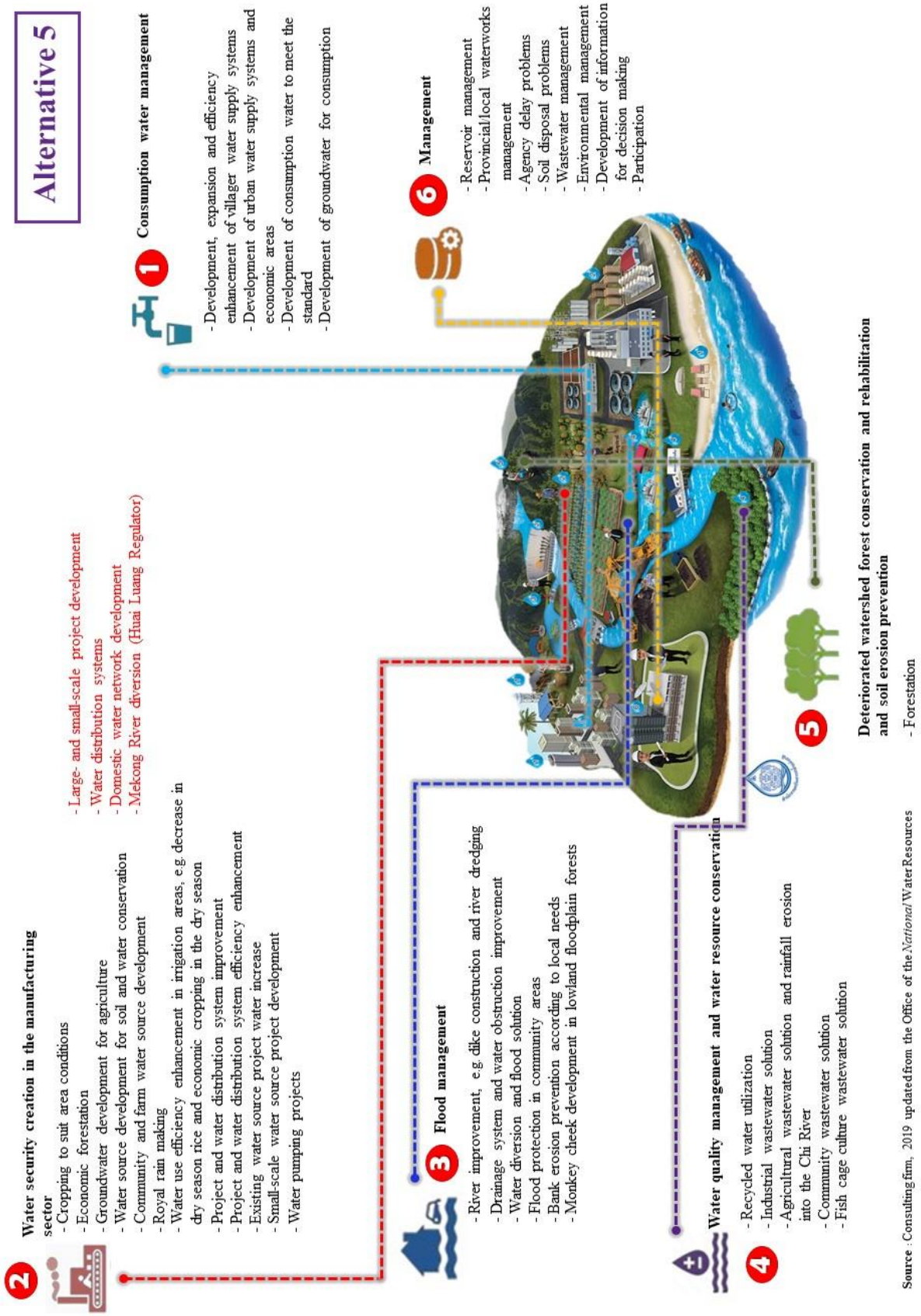


Figure 4.5-1 Alternative 5: Development of Business Agriculture as the Center of the Greater Mekong Subregion

1.4) Income distribution will be better by bridging the gap of rural and urban incomes. Farmers will also have more income.

2) Alternative 5 supports development of the Chi River Basin to be the center of the Greater Mekong Subregion because water provision is a basic factor for developing business agriculture, industry, tourism, economic areas and urban areas supporting the entire development in terms of upstream and midstream areas.

2.1) Provision of water: Water stored in the Chi River Basin will increase by 1,532 MCM and more water will be diverted from the Mekong River to the Chi River Basin to be sufficient for irrigation and benefiting areas of 9.55 million rai, which are the production source of agricultural crops, e.g. jasmine rice, economic crops, energy crops, herbal crops, etc.

2.2) Water in the agricultural business: Agricultural products, e.g. jasmine rice, organic jasmine rice, organic rice, sugarcane, cassava and economic crops will be used to develop food processing industry, agricultural industry and biotechnology industry with other regions and neighboring countries.

2.3) Development of herbal processed products will lead to development of the comprehensive medical industry with other regions and neighboring countries

2.4) Water will be sufficient to support and promote farmers to plant crops which are farmers' strengths in each area and to increase water value for production, as well as to enhance the quality of agricultural products.

3) The northeastern industry development to Thailand 4.0 currently faces water shortage for consumption, agriculture, industry and tourism. Alternative 5 will provide sufficient and stable water, which is a key base for developing the quality of peoples' lives in the river basin, will provide an opportunity for developing agriculture, industry and tourism so as to develop the Chi River Basin to be the center of the Greater Mekong Subregion for developing business agriculture, tourism and industry leading to Thailand 4.0.

Following the assessment of different alternatives, Alternative 5 is suitable for developing the Chi River Basin area to be stable, wealthy, sustainable and the center of the Greater Mekong Subregion.

As for water security creation in the manufacturing sector by diverting the Mekong River, Huai Luang Regulator has been considered as an alternative to provide sufficient water because of its readiness than other projects. The project consists of Huai Luang Regulator and Ban Daeng Mueang Pumping Station. The construction of Huai Luang was completed in 2002, while Ban Daen Mueang Pumping Station began its construction in fiscal year 2018. It was scheduled to be completed in fiscal year 2026 (nine years). Thus, it can be carried out immediately.

4.6 Development Plans for the Integrated Water Resources in the Chi River Basin

The development plans for the integrated water resources in the Chi River Basin took into account the solutions to social and environmental problems and economic development to increase incomes and upgrade the quality of life of people in the Chi River Basin area (the details of water resource development plans in the Chi River Basin are shown in the Strategic and Integrated Development Program Report), as summarized below.

4.6.1 Goals of Water Resource Development Plans in the Chi River Basin

The goals of the development plans for the integrated water resources in the Chi River Basin are as follows:

1) Solve basic problems in the Chi River Basin area in relation to water for domestic use and agricultural use.

2) Manage the environment for conserving and rehabilitating watershed forests and addressing the wastewater issue.

3) Mitigate the drought and flood issues.

4) Develop water resources in the Chi River Basin to develop agricultural industry in the Chi River Basin area.

5) Provide sufficient water for development of business agriculture, industry and tourism to develop the Chi River Basin area as the center of the Greater Mekong Subregion

4.6.2 Preparation of the Water Resources Development Plans

The preparation of the water resources development plans in the Chi River Basin took into account local needs identified in ten public hearings held in the Chi River Basin area and suitability in the economic, social and environmental dimensions. They consist of short-, medium-, and long-term water resources development plans, as outlined below:

1) The short-term (years 4-5) and medium-term programs (years 6-10) of the National Strategic Plan – Goals to address **social and environmental** issues were set. To achieve Goals 1-3, Alternative 3 was defined as the program for the development of the Chi River Basin area in line with the demand of most participants in the public hearings.

2) The medium (years 9-10) and long-term programs (years 11-20) of the National Strategic Plan – This was set under Goals 4 and 5. Alternative 5 was proposed for the development of the Chi River Basin area, which aims to increase income for people, create opportunities for **economic development in the Chi River Basin area** and nearby river basins, and provide water for agriculture, tourism, and industry to provide people in the Chi River Basin area with good quality of life and income stability, prosperity, and sustainability.

4.6.2.1 Short- and Medium-term Programs

The short- and medium-term programs, which are development plans according to Alternative 3 within years 4-10 of the National Strategic Plan B.E. 2564-2570 (2021-2027), can be immediately implemented. They comprise plans for solving social and environmental problems, as follows:

1) Basic Problem Solving Program
   - Aspect 1: Consumption-based water management
     - 1.1 Consumption-based water provision
     - 1.2 Local administrative organizations' water supply system improvement projects
     - 1.3 Local administrative organizations' water source development projects
   - Aspect 2: Creation of water security in the manufacturing sector.
     - 2.1 Management of rainfed agricultural areas.
     - 2.2 Provision of water sources in rainfed agricultural areas.
   - Aspect 4: Water quality management and water resource conservation.
     - 4.1 Recycling of treated used water.
   - Aspect 5: Conservation and rehabilitation of degraded watershed forests and soil erosion.
     - 5.1 Forestation (rai)
     - 5.2 Watershed weirs (permanent weirs)
   - Aspect 6: Management.
2) Drought, Flood and Wastewater Mitigation Program
   - Aspect 2: Creation of water security in the production sector.
     - 2.1 Enhancement of the efficiency of water use in irrigation areas.
     - 2.2 Project improvement, maintenance and optimization.
     - 2.3 Development of small-scale water source and pumping projects.

Aspect 3: Flood management
- 3.1 Flood prevention, e.g. river, drainage and waterway obstruction improvement
- 3.2 Prevention of bank erosion based on local needs.
- 3.3 Development of monkey cheeks in lowland floodplain forest areas.
- 3.4 Floodways

Aspect 4: Water quality management and water resource conservation.
- 4.1 Wastewater solution.

Aspect 6: Management

4.6.2.2 Medium- and Long-term Programs

The medium- and long-term program are work plans according to Alternative 5 within years 9-20 of the National Strategic Plan B.E. 2564-2580 (2021-2037) as a result of available time for preparing feasibility study, environmental impact assessment, and detailed surveys and design in years 4-17 (2021-2034). They are the development programs which are continuous from Alternative 3 for economic development, and aim to increase income and provide opportunities for economic development in the Chi River Basin to achieve security, prosperity and sustainability, consisting of:

1) Drought, Flood and Wastewater Mitigation Program
   Aspect 3: Management of drought and flood
   - 3.1 Flood protection in urban communities
   - 3.2 Water diversion to solve floods

   Aspect 6: Management.
2) Water Source Development for Economic Development Program
   Aspect 2: Creation of water security in the manufacturing sector.
   - 2.1 Development of water source projects in the river basins at their full potential.
     1) Development of large- and medium-scale water source projects at their full potential in the Chi River Basin.
     2) Development of water distribution systems.
     3) Development of domestic water networks.
   - 2.2 Increase of water in the Chi River Basin by diverting water in the Mekong River (Huai Luang Regulator)

   Aspect 6: Management

Integrated water resource development plans in the Chi River Basin area consist of three-group plans in accordance with suitable development alternatives, as shown in **Table 4.6.2-1**. Water resource development plans are grouped in six aspects in accordance with the master plan of 20-year water resource management, as shown in **Table 4.6.2-2**. Projects specified in such plans are only some plans collected from relevant state agencies and local peoples' requirements according to the study period.

4.7 Integration of Development Plans as the Center of the Greater Mekong Subregion

As water is a basic factor for livelihood, agricultural production, as well as urban, industrial and tourist development, the following water resource operations must be carried out to develop the Chi River Basin area focusing on development of business agriculture, urban economic areas, industrial areas and tourism.

Table 4.6.2-1 Integrated Water Resource Development Plans in the Chi River Basin (Three-Group Plans in Line with Appropriate Development Alternatives)

No	Plans	Number of projects	Development plans, year																	
			Short-term plans		Medium-term plans					Long-term plans										
			4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
			2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	
1.	**Basic problem-solving program**																			
	Aspect 1 Consumption-based water management																			
	1.1 Consumption-based water provision	615																		
	1.2 Local administrative organizations' water supply system improvement projects	876																		
	1.3 Local administrative organizations' water source development projects	3,396																		
	Aspect 2 Water security creation in the manufacturing sector																			
	2.1 Rainfed agricultural area management (economic forest cultivation 66,062 rai)	-																		
	2.2 Water source provision in rainfed agricultural areas	1,149																		
	Aspect 4 Water quality management and water resource conservation																			
	4.1 Recycled water utilization	-																		
	Aspect 5 Degraded watershed forest conservation and soil erosion prevention																			
	5.1 Forestation (831,406 rai)	-																		
	5.2 Watershed weirs (permanent weirs)	148																		
	Aspect 6 Management																			
2.	**Drought, flood and wastewater mitigation program**																			
	Aspect 2 Water security creation in the manufacturing sector																			
	2.1 Water use efficiency enhancement in irrigation areas (increasing an cultivation area of 66,460 rai)	-																		
	2.2 Project maintenance improvement and efficiency enhancement	444																		
	2.3 Small-scale water source development and pumping projects	546																		
	Aspect 3 Flood management																			
	3.1 Flood prevention, e.g. river, drainage and waterway obstruction improvement	350																		
	3.2 Bank erosion prevention in accordance with local needs	76																		
	3.3 Monkey cheek development in lowland floodplain forests	264																		
	3.4 Floodways *	-																		
	3.5 Flood prevention in community areas	32																		
	3.6 Water diversion to solve floods	4																		
	Aspect 4 Water quality management and water resource conservation																			
	4.1 Wastewater solution	36																		
	Aspect 6 Management																			
3.	**Water source project development program for economic development**																			
	Aspect 2 Water security creation in the manufacturing sector																			
	2.1 Water source project development in the Chi River Basin at full potential																			
	1) Medium- and large-scale project development	158																		
	2) Water distribution system development	46																		
	3) Domestic water network development	16																		
	2.2 Water availability increase in the Chi River Basin by Mekong diversion																			
	1) Mekong diversion (Huai Luang Regulator)	1																		
	Aspect 6 Management																			
	Total **	**8,008**																		

Remark : *Preliminary study/**Excluding economic forest cultivation areas (66,062 rai), reforestation for conservation of watershed forests (831,406 rai), watershed weirs (148 locations) and Mekong diversion (Huai Luang Regulator) for one project

Study and design Construction Management

Source: Analyzed by the consultants, 20109

Table 4.6.2-2 Integrated Water Resource Development Plans in the Chi River Basin (Six-Aspect Plans According to the 20-Year Water Resource Management Master Plan)

No	Aspect/plan	Number of projects	Plan, year																	
			Short-term plans		Medium-term plans					Long-term plans										
			4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
			2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	
1.	**Aspect 1 Consumption-based water management**																			
	1.1 Consumption-based water provision	615																		
	1.2 Local administrative organizations' water supply system improvement projects	876																		
	1.3 Local administrative organizations' water source development projects	3,396																		
2.	**Aspect 2 Water security creation in the manufacturing sector**																			
	2.1 Rainfed agricultural area management (economic forest cultivation 66,062 rai)	-																		
	2.2 Water source provision in rainfed agricultural areas	1,149																		
	2.3 Water use efficiency enhancement in irrigation areas (increasing an cultivation area of 66,460 rai)	-																		
	2.4 Project maintenance improvement and efficiency enhancement	444																		
	2.5 Small-scale water source development and pumping projects	546																		
	2.6 Water source project development in the Chi River Basin at full potential																			
	1) Medium- and large-scale project development	158																		
	2) Water distribution system development	46																		
	3) Domestic water network development	16																		
	2.7 Water availability increase in the Chi River Basin by Mekong diversion																			
	1) Mekong diversion (Huai Luang Regulator)	1																		
3.	**Aspect 3 Flood management**																			
	3.1 Flood prevention, e.g. river, drainage and waterway obstruction improvement	350																		
	3.2 Bank erosion prevention in accordance with local needs	76																		
	3.3 Monkey cheek development in lowland floodplain forests	264																		
	3.4 Floodways *	-																		
	3.5 Flood prevention in community areas	32																		
	3.6 Water diversion to solve floods	4																		
4.	**Aspect 4 Water quality management and water resource conservation**																			
	4.1 Recycled water utilization	-																		
	4.2 Wastewater solution	36																		
5.	**Aspect 5 Degraded watershed forest conservation and soil erosion prevention**																			
	5.1 Forestation (831,406 rai)	-																		
	5.2 Watershed weirs (permanent weirs)	148																		
6.	**Aspect 6 Management**																			
	Total **	**8,008**																		

Remark : *Preliminary study/**Excluding economic forest cultivation areas (66,062 rai), reforestation for conservation of watershed forests (831,406 rai), watershed weirs (148 locations) and Mekong diversion (Huai Luang Regulator) for one project

Study and design Construction Management

Source: Analyzed by the consultants, 20109

1) Provide sufficient water to be stable to serve various activities

2) Increase water value by using water in the business, processing agriculture, and use water for consumption in urban communities, industry and tourism

3) Manage water efficiently and integrate development plans of the Chi River Basin as the center of the Greater Mekong Subregion, as well as water resource management strategic plans, and transport and logistics, agricultural business, urban and tourism development plans, as shown in **Figure 4.7-1**.

4.7.1 Water Resource Management Plans

To provide water to solve poverty, increase income, provide sufficient water, solve floods and wastewater problems, as well as to provide an opportunity for the country's economic development, the operations will be carried out in six aspects in accordance with the master plan of 20-year water resource management: 1) consumption-based water provision, 2) water security creation in the manufacturing sector, 3) flood management 4) water quality management and water resource conservation, 5) degraded watershed forest conservation and soil erosion protection, and 6) management so as to increase economic development in the Chi River Basin by developing diversion projects leading to economic, social and environmental sustainability and balance.

1) Consumption-based water management

1.1) Improve village water supply systems and construct new water supply systems

1.2) Construct PWA water supply systems

1.3) Construct village water supply systems to meet the consumption-based water standard

1.4) Drill groundwater wells and install pumps to supplement water for groundwater supply systems

2) Creation of water security in the manufacturing sector

2.1) Group agricultural areas in accordance with rainfall and groundwater potential into eight zones

2.2) Promote local people to change and use areas for mixed cropping

2.3) Conserve and rehabilitate natural water sources and improve natural water sources

2.4) Develop water distribution systems for agriculture (pumping using electricity and solar cell)

2.5) Dig farm ponds and construct water sources outside irrigation areas

2.6) Make artificial rain

2.7) Reduce dry season rice and economic crop cultivation

2.8) Improve reservoirs, weirs, pumping stations, distribution canals and irrigation structures

2.9) Enhance the efficiency of irrigation and storage systems of irrigation structures

2.10) Increase the storage potential of reservoirs, weirs and regulators

2.11) Construct reservoirs, weirs, regulators and small-scale irrigation structures

2.12) Construct pumping stations

2.13) Construct medium- and large-scale projects comprising dams, reservoirs, weirs, regulators and irrigation structures

2.14) Construct irrigation canals, distribution canals and irrigation systems

2.15) Divert water within the Chi River Basin from one source to other sources.

2.16) Divert the Mekong River

Master Plan on Water Resources Management in Six Aspects

Chi River Basin Development Plan as the Center of the Greater Mekong Subregion

2 Water security creation in the manufacturing sector

- Group eight agricultural zones according to rainfall and groundwater potential
- Promote local people to change and use areas for mixed farming
- Conserve and rehabilitate natural water sources
- Develop agricultural water distribution systems (pumping and solar cell)
- Dredge farm ponds and construct water sources outside irrigation areas
- Make artificial rain
- Reduce dry season rice cropping and plant economic crops in the dry season
- Improve reservoirs, weirs, pumping stations, irrigation canals and irrigation structures
- Increase irrigation efficiency and storage systems of irrigation structures
- Increase potential of reservoir, weir and regulator storage
- Construct reservoirs, weirs, regulators and small-scale irrigation structures
- Construct pumping stations
- Construct medium- and large-scale projects: dams, reservoirs, irrigation canals and irrigation systems
- Construct irrigation canals, distribution canals and irrigation systems
- Divert water within the Chi River Basin from one source to other sources
- Divert the Mekong River

1 Consumption-based water management

- Improve village water supply systems and construct new water supply systems
- Construct water supply systems for the Provincial Waterworks Authority
- Construct village water supply systems to meet the standard of consumption-based water
- Drill groundwater wells and install pumps to provide sufficient water for groundwater water supply systems

3 Flood management

- Construct dikes and retention walls, and dredge rivers
- Improve floodways, and improve bank slopes and retention walls
- Divert water to solve floods
- Construct community flood protection systems
- Construct river bank protection in accordance with the community demand
- Develop monkey cheeks in lowland floodplain forest areas

4 Water quality management and water resource conservation

- Use the recycled water
- Construct new wastewater treatment systems and improve the existing ones to be more efficient
- Solve wastewater from agriculture and rainfall into the Chi River
- Solve community wastewater problems
- Solve wastewater from cage fish culture

5 Degraded watershed forest conservation and soil erosion protection

- Plant forests in watershed forests in line with nearby forest structures
- Construct weirs in rainfed forests

Develop transport systems, business, agriculture, economic areas and tourism to be the center of the Greater Mekong Subregion

Business-related agricultural development to be the center of the Greater Mekong Subregion

Provision of sufficient water and security in water use for economic development

6 Management

- Manage reservoirs
- Manage provincial and local water supply systems
- Delay of agencies
- Soil from dredging
- Wastewater management
- Environmental management
- Develop data for decision-making
- Participation in the implementation of plans at the policy, plan and operation levels in accordance with the master plan of 20-year water resource management

Transport and logistics system development plans

1. Development of double-track railways and high-speed trains linking to Lao PDR and People's Republic of China (Modal Shift Multimode) to reduce transport costs
2. Development of road networks linking to the Mekong River Basin countries (Regional Connectivity) as a gateway
3. Development and improvement of transport systems (mobility) to upgrade the quality of life and peoples' life safety
4. Development of Khon Kaen Airport as the transport center
5. Development of central markets and agricultural products in big cities distributed along the Chi River Basin to connect to central markets
6. Development of central markets to collect and distribute products linking to major domestic economic areas (Intercity) in Khon Kaen Province
7. Development of agricultural databases and connectivity with farmers
8. Establishment of the agricultural product sale center in major city and district areas
9. Development of the agricultural product online buying system linking to communities and farmers

Agricultural business development plans

1. Pilot areas for promoting business agriculture under the Nong Wai and Lam Pao irrigation projects and agricultural areas benefiting from the operation and maintenance of both projects related to biological agricultural crops, jasmine rice economic areas, grass planting areas, beef cattle raising areas, etc.
2. Expansion of business-based agricultural areas and establishment of business networks with soil and water readiness
3. Promotion of agricultural processing industry and OTOP products to increase incomes in the Chi River Basin area
4. A hub of agricultural processing industrial economy in upstream, midstream and downstream areas
5. Promotion and support of agricultural products, good agricultural practices and precision agriculture in different provinces in the Chi River Basin
6. Promotion and support of agricultural institutes and community enterprises to plant agricultural crops and develop quality agricultural products in line with the demand of supply chain of agricultural products in the areas
7. Management of efficient logistics systems in terms of transport costs, on-time delivery and product reliability

Urban and tourism development plans

1. Enforcement of town plans in various areas
2. Development of Khon Kaen to become the regional economic center and to connect to lower northeastern tourism development areas and Mekong tourism development areas
3. Development of famous tourist sites in provinces to connect to each other
4. Construction of flood protection systems in urban communities and economic areas
5. Promotion, support and public relations of natural, cultural and traditional tourist attractions, local wisdom and prehistoric rock sources (dinosaur), etc.

Figure 4.7-1 Integration of Chi River Basin Development Plans as the Center of the Greater Mekong Subregion

3) Flood management
   3.1) Construct dikes and retention walls as well as dredge streams
   3.2) Improve drainage channels, bank slopes and retention walls
   3.3) Divert water to solve floods
   3.4) Construct community flood protection systems
   3.5) Construct river bank protection in accordance with community needs
   3.6) Develop monkey cheek areas in lowland floodplain forests
4) Water quality management and water resource conservation
   4.1) Use recycled water
   4.2) Construct new wastewater treatment systems and improve the existing ones
   4.3) Solve wastewater problems due to agriculture and rainfall leading to erosion in the Chi River
   4.4) Solve community wastewater problems
   4.5) Solve wastewater problems related to fish cage culture
5) Conservation and rehabilitation of degraded watershed forests and soil erosion.
   5.1) Grow forests in watershed forests in line with nearby forest structures
   5.2) Construct weirs in watershed forests
6) Management
   6.1) Manage reservoirs
   6.2) Manage provincial and local water supply systems
   6.3) Manage the delay of agencies
   6.4) Manage soil problems due to dredging
   6.5) Solve wastewater problems
   6.6) Manage the environment
   6.7) Develop data for decision-making
   6.8) Participate in the operation at the policy, plan and operation levels in accordance with the master plan of 20-year water resource management

The master plan of 20-year water resource management involves provision of sufficient, secure and stable water to provide an opportunity for economic development by integrating development plans to develop the Chi River Basin as the center of the Greater Mekong Subregion.

4.7.2 Chi River Basin Development Plan as the Center of the Greater Mekong Subregion

To develop the Chi River Basin area to become the center of the Greater Mekong Subregion, water resource management strategic plans must be integrated with other development plans in the Chi River Basin as follows:

1) Transport and logistics system development plans
2) Agricultural business development plans
3) Urban and tourism development plans

4.7.2.1 Transport and logistics system development plans

Transport and logistics system development plans are to distribute agricultural product channels and to transport agricultural products from producers to consumers rapidly in the required period. They are:

1) Development of double-track railways and high-speed trains linking to Lao PDR and People's Republic of China (Modal Shift Multimode) to reduce transport costs

2) Development of road networks linking to the Mekong River Basin countries (Regional Connectivity) as a gateway

3) Development and improvement of transport systems (mobility) to upgrade the quality of life and peoples' life safety

4) Development of Khon Kaen Airport as the transport center

5) Development of central markets and agricultural products in big cities distributed along the Chi River Basin to connect to central markets

6) Development of central markets to collect and distribute products linking to major domestic economic areas (Intercity) in Khon Kaen Province

7) Development of agricultural databases and connectivity with farmers

8) Establishment of the agricultural product sale center in major city and district areas

9) Development of the agricultural product online buying system linking to communities and farmers

4.7.2.2 Agricultural business development plans

Agricultural business development plans involve processing and value adding of agricultural products comprising:

1) Pilot areas for promoting business agriculture under the Nong Wai and Lam Pao irrigation projects and agricultural areas benefiting from the operation and maintenance of both projects related to biological agricultural crops, jasmine rice economic areas, grass planting areas, beef cattle raising areas, etc.

2) Expansion of business-based agricultural areas and establishment of business networks with soil and water readiness

3) Promotion of agricultural processing industry and OTOP products to increase incomes in the Chi River Basin area

4) A hub of agricultural processing industrial economy in upstream, midstream and downstream areas

5) Promotion and support of agricultural products, good agricultural practices and precision agriculture in different provinces in the Chi River Basin

6) Promotion and support of agricultural institutes and community enterprises to plant agricultural crops and develop quality agricultural products in line with the demand of supply chain of agricultural products in the areas

7) Management of efficient logistics systems in terms of transport costs, on-time delivery and product reliability

4.7.2.3 Urban and tourism development plans

Urban and tourism development plans involve development to serve economic growth and link to tourist sites to support economic development in the Chi River Basin comprising:

1) Enforcement of town plans in various areas

2) Development of Khon Kaen as the regional economic center and to connect to lower northeastern tourism development areas and Mekong tourism development areas

3) Development of famous tourist sites in provinces to connect to each other

4) Construction of flood protection systems in urban communities and economic areas

5) Promotion, support and public relations of natural, cultural and traditional tourist attractions, local wisdom and prehistoric rock sources (dinosaur), etc.

Chapter 5

Driving Plans into Practice

Chapter 5
Driving Plans into Practice

5.1 Framework for Driving Plans into Practice

To drive the strategic environmental assessment for integrated water resource development in the Chi River Basin, the time temporal approach is used in accordance with the 20-year National Plan comprising four topics, namely 1) specifying the moving direction, 2) a guide plan for driving, 3) driving organizations and 4) components/structures for driving.

To present the overall management of integrated water resource development strategies, the essence was divided into the following six parts to drive plans into practice:

Part 1: This is the key element for setting the directions of development of water resources in the Chi River Basin, which is implemented in line with the national development directions under the 20-year National Strategy, with the "innovation" principle as the driver. The following topics are focused on: products, water resources, technology, management, process, integration of all sectors, society, as well as development of water resources and utilization of water resources to be worthwhile and beneficial.

Part 2: The Master Plan for Water Resources are guidance plans based on the principle "sufficiency economy at all levels from the household, firm, community, basin to northeastern levels. As for household, firm and community levels, water reserved systems for “basic self-reliance” should be provided.

Part 3: Integration/monitoring of the SEA report preparation and direction planning of the ONWR, by the Academic and Technical Steering Committee, will carry out monitoring to ensure that the compliance with the TOR and academic contents, as well as techniques for strategy analysis based on the academic principle of SEA and SIDP.

Part 4: Proposing the SEA/ SIDP reports to the River Basin Committee and all relevant sectors to obtain approval for the ONWR to screen and present to the National Water Resources Committee (NWRC) to present to the Cabinet.

Part 5: Development/operation in line with the results of alternative analysis in accordance with the six water resource development aspects by 1) coordinating with agencies responsible for correcting and improving programs/projects, 2) integrating programs/projects and joint operation of different agencies, 3) assessing impacts and formulating prevention and mitigation measures, 4) brainstorming ideas from all sectors and 5) monitoring and assessing impacts.

In addition, the operation involves 37 acts (including the Water Resources Act, B.E.2561 (2018) related to water resource management. In principle, each law relates to law enforcement areas in compliance with relevant acts and objectives on the use of resources.

Part 6: Monitoring and evaluation of the results and outcomes of the Strategic Plans by 1) monitoring and evaluating the results of programs/projects and specified indicators, 2) monitoring and evaluating the field inspection and opinion survey from those who are directly affected by the project, and 3) improving programs to meet the target goals. The development results are to ensure economic, social and environmental balance to be consistent with the 20-years national strategy plan and to ensure sustainability and security in line with SDG plans.

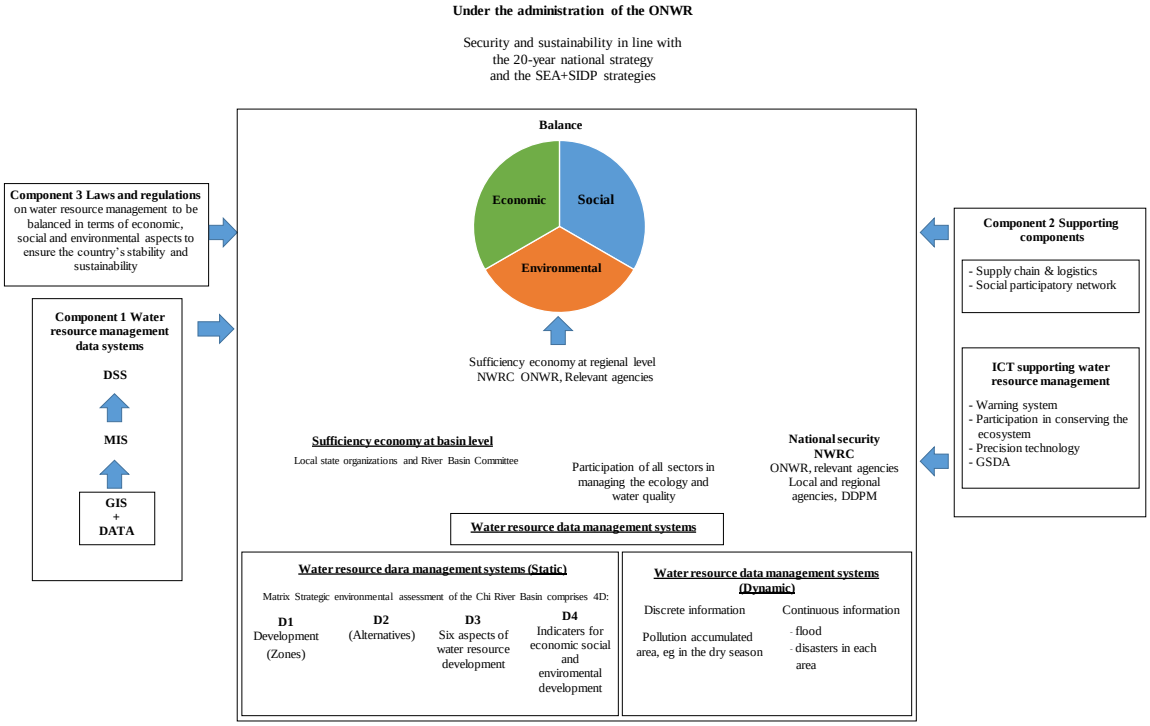
5.2 Management of Water Resources Big Data

Big data structures for water resource management are shown in **Figure 5.2-1** consisting of the three major components:

Component 1 Water resource management data systems comprise river basin data, physical characteristics, flood, drought and wastewater problems, basic information on water resources, water resource management plans, as well as economic, social and environmental data, etc.

Component 2 Supporting components include supply chain, product logistics, participatory networks, agencies and development plans, information communication systems supporting water resource management.

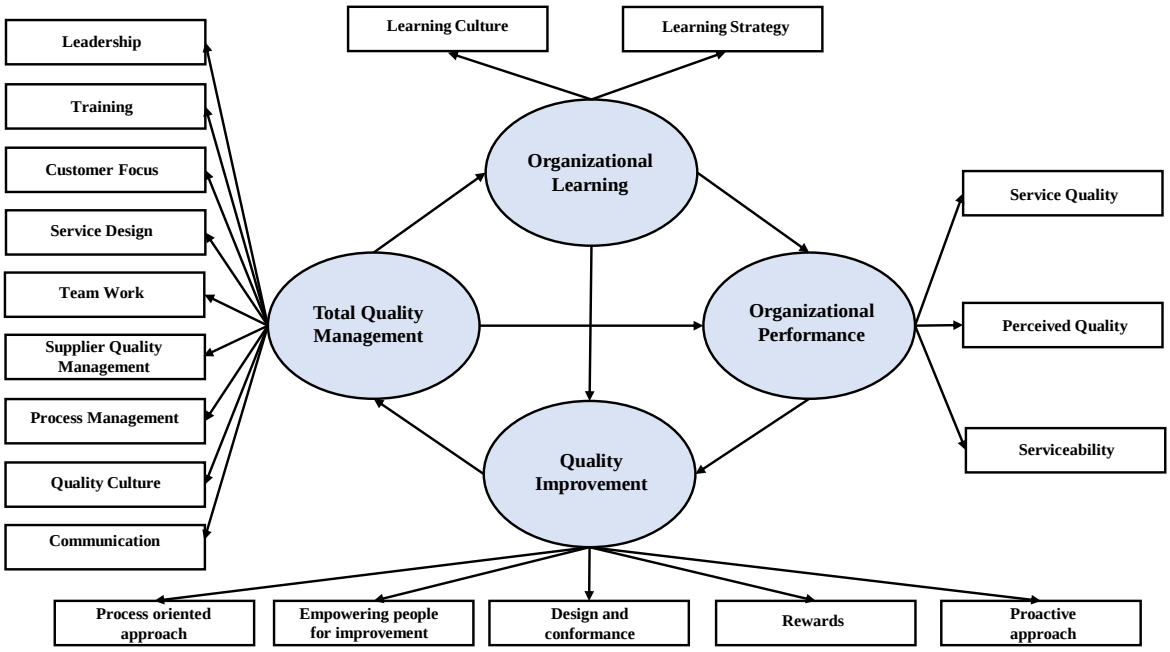
Component 3 Laws and regulations on water resource management to be balanced in terms of economic, social and environmental aspects to ensure the country's stability and sustainability



Source: Analyzed by the consultants, 2019

Figure 5.2-1 Big Data Structures for Managing Water Resources in the Chi River Basin under the Administration of the ONWR

Management of water resource big data to drive the strategic environmental assessment and water resource development (**Figure 5.2-2**) in the Chi River Basin is as follows:



Source: Analyzed by the consultants, 2019

Figure 5.2-2 Model of Water Resource Big Data Management

1) Total quality management (TQM) is a key component as a framework for driving the strategic environmental assessment, developing water resources in the Chi River Basin, managing the total quality management, which is a direction management for the national development over the next 20 years. The principle "innovation" is adhered to drive the direction and integration of the strategic environmental assessment, as well as strategic and integrated development program of the river basin. They are plan for developing water resources in the Chi River Basin based on the principle of "sufficiency economy" at all levels of basin, community, business and household.

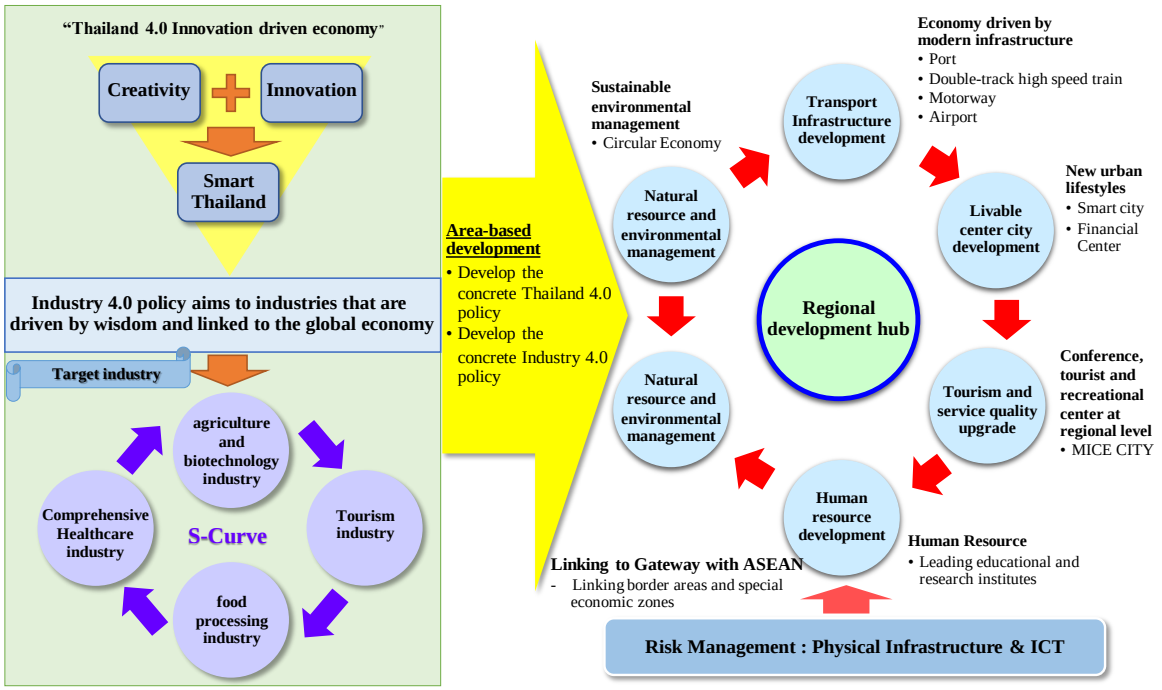
2) Organizational learning – All organizations that participate in management and water resource benefit users and managers. It is a learning organization for both the Water Resources Act for basic water management and risk management. The Water Resources Act gave roles to local government organizations as an organization to consider according to the to the guidelines specified by the National Water Resources Committee. The River Basin Committee acts as an organization to approve the use of water in each section. According to the practice, as the Water Resources Act refers to management or empowerment at the bottom level to drive water resource strategic plans, except for the case of large-scale water source development crossing river basins covering a vast area. The operation is based on both the current and future prospects in terms of economic, social and environmental aspects. The heads of government agencies were assigned to be responsible for consideration with the National Water Resources Committee's approval.

3) Organization performance – The ONWR acts as a secretary and the National Water Resources Committee acts as an organization to coordinate and integrate water resource development at the **bottom level** to empower local administrative organizations and river basin committee, at the **moderate level** of relevant public agencies and regional public agencies, and at the **top level** of the National Water Resources Committee so that development of water resources follow the master plan by taking into account the quality of operation to make all sectors satisfied in coordination and integration in accordance with the authority scope of laws of each public agency that are public interest and national interest to ensure security and sustainability of current and future resources.

4) Quality improvement – The ONWR plays a role in monitoring and evaluation in accordance with water resource master plan in order to improve the quality of water resource development and to achieve the 20-year water resource development plan in the Chi River Basin.

5.3 Integrated Plans as the Center of the Greater Mekong Subregion

The horizontal model involves the integration of development plans to develop the Chi River Basin area to be the center of the Greater Mekong Subregion. There are six aspects of managing water resources, developing business-based agriculture to be the center of the Greater Mekong Subregion relating to the coordination/integration of transport and logistics development plans, agricultural business and tourism development plans. Water resources are a push engine for developing the center of the Greater Mekong Subregion. Under the 20-year national development plans and the S-curve target industry structure, water resources support the development of the four target industries in the (**Figure 5.3-1**) comprising 1) agriculture and biotechnology industry 2) food processing industry 3) tourism industry and 4) comprehensive healthcare industry. Khon Kaen Province is the hub of the northeastern development, whereby the 20-year national development plans and Thailand 4.0 will be formulated to serve as a pull engine supported by water resource development plans.



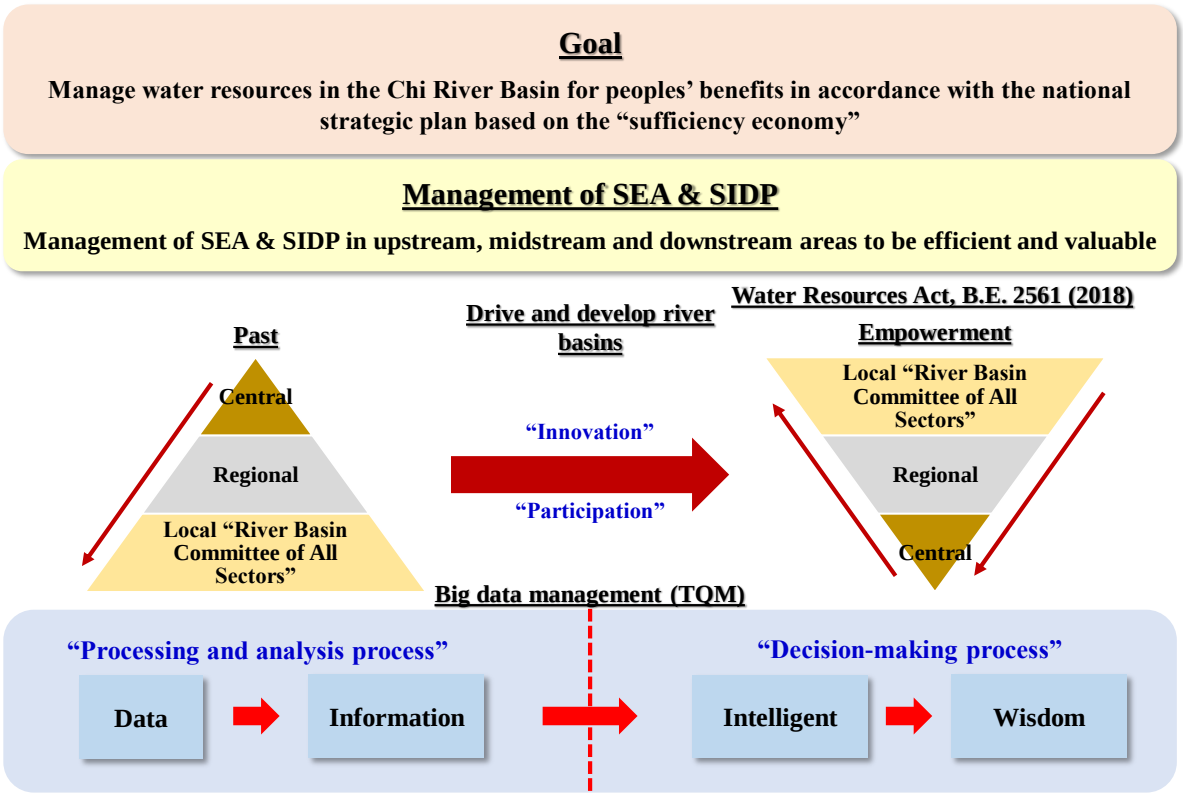
Source: Analyzed by the consultants, 2019

Figure 5.3-1 Framework for Developing Northeastern Areas to Achieve Thailand 4.0 Goals and the 20-Year National Strategic Plans

5.4 Summary of the Overall Strategic Environmental Assessment of the Chi River Basin

Figure 5.4-1 shows the overall strategic environmental assessment of the Chi River Basin to serve as a push engine for action plans. Goals include the management of water resources in the Chi River Basin for peoples' benefits in accordance with the national strategic plan based on the "sufficiency economy" (the 20-year national development plan) in line with the 12th National Economic and Social Development Plans.

The management of SEA&SIDP in upstream, midstream and downstream areas (5 Zones) to be efficient and valuable and the development of river basins to be consistent with the Water Resources Act B.E. 2561 (2008) based on the Big Data Management (Total Quality Management) leading to the decision-making process of all relevant sectors.



Source: Analyzed by the consultants, 2019

Figure 5.4-1 Summary of Strategic Environmental Assessment of the Chi River Basin

Chapter 6

Impact Mitigation and Monitoring Measures

Chapter 6
Impact Mitigation and Monitoring Measures

The implementation of the development plans of water resources in the Chi River Basin may have impacts on natural resources and the environment in the three dimensions – economic, social and environmental dimensions. Thus, there is a need to provide impact mitigation and monitoring measures to prevent or minimize potential adverse impacts or make them at an acceptable for people; prepare plans for promoting benefits; and monitor the operation to assess the effectiveness in line with development plans to achieve goals of balanced and sustainable environmental development. The details presented in the ***Impact Mitigation and Monitoring Measures Report*** are outlined as shown in **Table 6-1**.

Table 6-1 Summary of Impact Mitigation and Monitoring Measures

Impact mitigation measures	Impact monitoring measures
Economic dimension: Stable economic development to increase income and peoples' quality of life	
- Promoting local investments using local uniqueness to develop and add the value to local products. - Promoting local job creation - Promoting job development in line with local ways of life.	- Monitoring and assessing the income of people in the Chi River Basin area. - Monitoring and assessing the unemployment and migration of workers in the Chi River Basin area. - Monitoring and evaluating the promotion of low-water use plants and economic crops among farmers.
Social dimension: Focusing on response to basic necessities through thorough development and people's access to water	
- Improving the efficiency of waterworks services in urban and rural communities. - Campaigning for, and promoting, efficient water use among the general public in line with utilization in different activities. - Promoting decentralization of local administrative organizations and promoting community roles and participation in maintaining, conserving and using water resources in a balanced and fair manner. - Planning water management with local communities. - Providing opportunities for all sectors to take a greater part in water maintenance and management monitoring with government agencies to ensure sustainable water resources use. - Providing fair compensation and remedy for affected people.	- Monitoring the efficiency of the village waterworks. - Monitoring the efficiency of the waterworks in urban communities and economic areas. - Monitoring and evaluating the efficiency of water management (carried out by government agencies and all relevant sectors) - Monitoring the provision of compensation and remedy for affected persons. - Monitoring the risks of chemical exposure.

Table 6-1 Summary of Impact Mitigation and Monitoring Measures (Cont'd)

Impact mitigation measures	Impact monitoring measures
Environmental dimension: Focusing on development leading to balance with environment through prevention, rehabilitation and restoration of natural resources and environment for sustainable resource use	
1. Recycled water - Promoting and supporting research and development on applying clean technology to reduce waste and pollution. - Campaigning for, and promoting the use of treated water suiting types of activities to ensure worthwhile water resource use. **2. Forest resources** - Defining clear boundaries of forest reserves, conservation forests, and economic forests in the Chi River Basin area and announcing the boundaries to people to prevent forest encroachment and reduce conflict on the state boundaries - Specifying types of land use based on the town planning law in accordance with the potential of natural resources and the environment in the Chi River Basin area to prevent forest encroachment for other types of use. - Promoting the cultivation of legal economic trees outside the forest areas and in private areas to increase forest areas and generate community income. - Conducting public relations and training to equip the general public with the knowledge and understanding of land use regulations in conservation areas to prevent land encroachment. - Carrying out public relations to encourage all sectors to participate in forest conservation to ensure perfect forest conditions. - Developing and improving degraded forests and encouraging all sectors to carry out reforestation to increase forest areas. **3. Quality of surface water bodies** - Installing checkpoints and a monitoring system to control the quality of surface water resources - Encouraging local administrative organizations to have wastewater treatment systems in line with area potential. - Promoting the private sector's role in wastewater management to enhance water management efficiency. - Promoting a reduction in the use of agricultural chemicals and promoting organic farming. - Conserving and rehabilitating degraded public water sources	- Monitoring and evaluating of growing forests in watershed forest areas. - Monitoring the change in land use in accordance with the town planning law based on the potential of natural resources and the environment. - Monitoring the quality of water in natural water bodies with wastewater treatment. - Monitoring the quality of water treated by establishments. - Monitoring the efficiency of the central wastewater treatment system of community and urban areas. - Monitoring and being strict with law enforcement to ensure that wastewater drainage meets specified standards. - Monitoring and evaluating organic farming promotion.

Source: Analyzed by the consultants, 2019

Chapter 7

Public Relations, Mass Relations and Participation

Chapter 7
Public Relations, Mass Relations and Participation

The Project on the Study on the Chi River Basin Strategic Environmental Assessment has been implemented step by step by means of the Strategic Environmental Assessment (SEA), which is a systematic process used to support decision-making on the development of policies, plans, and programs (PPPs) taking into account environmental factors in conjunction with economic, social and technological factors and other factors and provides the opportunities for all relevant sectors to contribute to sustainable development. To result in the Project achieving its objectives with the ultimate goal to create acceptance and support for the Project without any conflict and allow all sectors to acknowledge, think, act, evaluate, and benefit to create a sense of shared responsibility for the Project, which starts from the strategic environmental assessment to the end of the process of the preparation of the Strategic Plans for the Integrated Development of Water Resources in the Chi River Basin. The details as shown in **Appendix H** (Appendix of the Strategic Environmental Assessment Report) are summarized as follows:

7.1 Objectives of the Implementation

1) To publicize project information and news and guidelines for project development to the target groups who are stakeholders from the policy level to the area level.

2) To provide opportunities for target groups at all levels to engage in sharing opinions, especially stakeholders in project implementation to manifest the actual problem conditions and the consistency with, and suitability for, social and community conditions in the project areas**.**

3) To provide exchanging and learning among the government agencies responsible for the project and stakeholders from all sectors to result in joint decision-making.

7.2 Summary of Participation Activities

Ten public relations, mass relations, and participation activities were carried out, including the 1st Chi River Basin Committee Meeting, on 14 May 2019; the Project Orientation Program, from 13 to 17 May 2019; the 1st Focus Group Meeting, from 24 June to 5 July 2019; the 2nd Focus Group Meeting, from 23 September to 4 October 2019; the 2nd Chi River Basin Committee Meeting, on 9 December 2019; the 3rd Focus Group Meeting, from 11 to 20 December 2019; the 3rd Chi River Basin Committee Meeting, on 15 January 2020; and the Project Closing Meeting on 13 to 17 January 2020, as well as the first and second perception creation activities through the media on September 7, 2019 and January 17, 2020, respectively. Their details are outlined below.

1) The 1st Chi River Basin Committee Meeting – Its objective was to define the scope of the study, study plan, and key issues of the Chi River Basin area, with the River Basin Committee considering, and providing opinions in the Inception Report, which was expected to result in joint decision-making. It was held on Tuesday 14 May 2019, from 08:30-12:00, at the Winner Room 8, Floor 7, Convenient Building, The Convenience Hotel, Mueang Khon Kaen District, Khon Kaen Province. Out of 31 members of the Chi River Basin Committee, 24 of them attended the meeting. The Committee members opined that water availability is important despite some impacts on the environment. They wanted the construction of projects which will increase water availability, e.g. dams, solar pumping stations, and pipeline-based water source development networks to solve the issues of drought, flooding and wastewater, water for agriculture, water for domestic use, and the environment. They suggested that a priority should be given to thorough water allocation for upstream-midstream -downstream areas and that the development of the Chi River Basin should be whole basin development to allow for integrated development (not area-based).

2) The Project Orientation Program: Its objectives were to define the scope of the study, study plan, key local issues, conditions of problems in the Chi River Basin area; publicize project information; and listen to opinions and suggestions from relevant persons. It was carried out from 13 to 17 May 2019, including five forums (consistent with the northeastern provincial cluster strategies). There were a total of 1,380 participants, most of whom were provincial/district/municipal/SAO civil servants, NGOs, members of the River Basin Committee, and water user groups in the project areas, respectively. These were the target groups of the meetings. Overall, the opinions of the stakeholders from the 1st to the 5th forums focused on river basin management which meets different demands, from people in upstream, midstream and downstream areas, and addresses local problems using the available budget the most efficiently.

3) 1st Focus Group Meeting – Its objectives were to define the scope of the study and study plan; publicize project information; and listen to local problem conditions, causes and solutions, area potential, and demand of people in Chi River sub-basin areas. It was held from 24 June to 5 July 2019, comprising a total of 10 forums (covering 27 sub-basins in the Chi River Basin). They were attended by 1,092 participants, most of whom were from local administrative organizations, village natural resources and environmental protection volunteer networks, water user groups in the project areas, and interested people, respectively.

The details of local potential; problem conditions, causes and solutions; and demand are outlined below:

- The potential of the area can be classified into three aspects: agriculture (prominent rice varieties and other economic crops), small-scale industry/household industry derived from traditional or modernized local wisdom and tourism (cultural tourism and natural tourism).
- Overall conditions of problems occurring in areas included in the Chi River Basin – All the areas experience the issue of drought, especially the shortage of water for agriculture, which occurs every year and is very severe. Some areas also suffer from the shortage of water for domestic use in the dry season. Concerning flooding, its severity varies from one area to another area, and it does not occur every year, depending on the amount of rainfall each year. Mostly, flooding occurs in community areas, and the local people conduct fishery during flooding instead of agriculture. The wastewater issue often occurs in the dry season and is severe during the low water year. It arises from chemical use in agricultural areas. In some areas, it is derived from factories and communities. The problem of saline soil occurs in some areas but is not serious. The issue of the quality of water for domestic use is serious in upstream and downstream areas. Overall, the local water management is significantly inefficient.

4) The 2nd Focus Group Meeting – It had the objective to review the guidelines for SEA study, summarize the conditions of problems in the river basin area, implementation progress, alternatives for the development of the Chi River Basin area (to select appropriate alternatives), as well as listen to the opinions and suggestions from stakeholders at the area level, which aimed to lead to joint decision-making. It was held 10 times, from 23 September to 4 October 2019 (in the same areas as the 1st Focus Group Meeting). It consisted of a total of 942 participants, most of whom were officers from local administrative organizations, community leader groups, and water user groups, respectively.

Summary of the group activities – They were divided into two parts: setting goals and directions of the development and consideration of appropriate alternatives for the development in the Chi River Basin area, as outlined below:

- **Setting the goals and directions for the development of the Chi River Basin area**, which considered three dimensions, based on the majority votes: economic dimensions, 32.41 percent, social dimensions, 27.69 percent, and environmental dimensions, 39.91 percent.
- **Consideration of appropriate alternatives (from the group process) –** All the meeting participants were asked to review the benefits and adverse impacts of the five alternatives under three dimensions: economic, social and environmental dimensions and select the one they considered to be suitable and adequate for the development. This involved the methods of casting a ballot and counting, as well as announcing the results. Preliminarily, it was concluded that from all the 10 forums, 50.60 percent of the participants regarded that Alternative 3 was suitable and adequate for the development in the Chi River Basin.

5) The 2nd Chi River Basin Committee Meeting – The meeting aimed to develop and assess the alternatives in order to identify potential alternatives and provide opinions on these alternatives; and identify indicators, impacts, and guidelines for impact assessment. The River Basin Committee provided opinions in the Interim Report, which was expected to result in joint decision- making. This meeting took place on Monday 9 December 2019, from 13:00 - 17:00 at the Siang Khaen Meeting Room, 2nd Floor, Old City Hall, Mueang Dstrict, Khon Kaen Province. Out of 31 Chi River Basin Committee members, 22 members (or their representatives) attended the meeting. The conclusion was the meeting participants agreed with the implementation guidelines based on the program framework and the alternative proposed in the Project Interim Report.

6) The 3rd Focus Group Meeting – Its objectives were to review the guidelines for the SEA study, present the results of the optimal alternative selection, draft the Strategic and Integrated Development Program of River Basin (SIDP), listen to opinions from people concerned in the river basin area, and listen to the opinions and suggestions from people concerned. It included 10 forums, from 11- 20 December 2019 (in the same areas as the 1st and 2nd Focus Group Meetings). From the 10 forums, there were altogether 870 participants, most of whom were from local administrative organizations, community leader groups, and water user groups, respectively.

Summary of the results of discussions – All the participants from all forums agreed with the priorities of solving the problems for individual areas, which served as the guidelines for developing programs on the development of the Chi River Basin area. Additional needs for local problem- solving were presented, e.g. stream dredging, bank protection, and provision of water for agriculture. For the development of the Chi River Basin area, the needs were incorporated in the plans/programs.

7) The 3rd Chi River Basin Committee Meeting is aimed at considering the draft final report. The contents include the results of the strategic environmental assessment and the preparation of the draft programs in accordance with the integrated and strategic development program. It was carried out on Wednesday 15 January, 2020 from 08.30-12.00 at the Mongkut Grand Ballroom, 2nd Floor, Kosa Hotel, Mueang District, Khon Kaen Province. Out of 31 Chi River Basin Committee

members, 17 members attended the meeting. The Chi River Basin Committee had an opinion that programs/projects can be adjusted to each area according to short- medium- and long-term plans. Short-term plans should be carried out by taking into consideration the solution of drought, flood and wastewater, as well as consumption-based water. The committee also worried about programs at different plans, because there were no agencies responsible for the projects. There should be a transitory provision to serve future improvement of plans.

8) Project Closing Meeting is aimed at publicizing the strategic environmental assessment report and the integrated and strategic development program report, and at listening to comments/suggestions from people concerned to result in joint decision-making. It was carried out at five forums (in line with the grouping of provincial northeastern strategies) from 13 to 17 January 2020. A total of 1,334 participants attended the meeting. Most are government officers at provincial and district levels, municipalities and sub-district administrative organizations, NGOs, river basin committees and water user groups living in the project areas, respectively, who are the target groups of the meeting. The overall opinions from the stakeholders from the 1st to the 5th forums stressed the solution to drought and appropriate water management in the areas.

9) The 1st perception creation activity through the media is aimed at letting mass media experience project areas as well as creating an understanding among stakeholders in project areas and among mass media for public relations. It was carried out on September 7, 2019 at Ubolratana Dam, Ubolratana District, Khon Kaen Province to monitor water situations in the Chi River Basin attended by central and local mass media from at least 10 news agencies with the following activities.

- Mass media reported the news on Deputy Prime Minister's inspection (General Prawit Wongsuwon)
- Director of Ubolratana Dam adressed welcome speech and summarized water situation at Ubolratana Dam.
- Secretary-General of the Office of the National Water Resources reported overall water situations in the Chi River Basin.
- Khon Kaen Governor reported drought situations and assistance to Khon Kaen Province.
- Mass media visited dam water levels and interviewed the Secretary-General of the Office of the National Water Resources.

After visiting and monitoring water resource management in northeastern areas and the Strategic Environmental Assessment of the Chi River Basin at Ubolratana Dam, Ubolratana District, Khon Kaen Province, **Mr. Somkiat Prajamwong, Secretary-General of the Office of the National Water Resources** provided the project information to the mass media. In summary, the Office of the National Water Resources has applied the SEA process to planning to solve water problems in the Chi River Basin in all dimensions, to create balance in economic development and environmental maintenance, and to promote sustainable quality of life of people.

10) The 2nd perception creation activity through the media is aimed at monitoring water shortage situations in the Chi River Basin and meeting stakeholders in the project areas, as well as creating an understanding among mass media for further public relations. It was carried out on January 17, 2020 in Nong Bua Lam Phu Province. It was attended by 11 news agencies. **Mr. Weangchai Kawpinit, Deputy Governor of Nong Bua Lam Phu Province** stated that Nong Bua Lam Phu Province is now facing drought and water shortage, which have been primarily solved. However, it is a good opportunity for those involved in the long-term. They will be informed of the project operation results in order to assess environmental potential and restrictions, and propose guidelines for developing the Chi River Basin area to achieve the goals specified in the 20-year national strategy "a developed country with security, prosperity and sustainability". In addition, **Mr. Terakom Ariyasoonthon, Director of Office of the National Water Resources, Regional Office 3** explained the project details and its results leading to further water management plans for the Chi River Basin.

Chapter 8

Conclusions and Recommendations

Chapter 8
Conclusions and Recommendations

8.1 Conclusions

1) The Chi River Basin spans approximately 49,130 km^2, which is approximately 30,706,152 rai (30.7 million rai). It covers 13 provinces, namely Kalasin, Khon Kaen, Chaiyaphum, Nakhon Ratchasima, Phetchabun, Maha Sarakham, Yasothon, Roi Et, Si Sa Ket, Nong Bua Lam Phu, Udon Thani, and Ubon Ratchathani. Almost all the river basin area is in Chaiyaphum, Khon Kaen, Kalasin and Roi Et provinces, respectively. The Chi River Basin comprises a total forest area of approximately 5,091,486 rai (5.09 million rai), which represents 16.58 percent of the river basin area, and comprises a total agricultural area of approximately 20,436,852 rai (20.44 million rai), representing 66.56 percent. The total area composed of soils which is suitable for crop cultivation spans 19,564,531 rai (19.56 million rai), representing 63.72 percent of the entire river basin area. It has an average annual rainfall of 1,188 mm and an average annual runoff of 11,994 MCM. It has a population of approximately 5,953,334. The water demand by all sectors amounts to 5,068 MCM; however, the water storage capacity of local large- and medium-scale projects is only 5,687 MCM.

2) **Forecast for the next 20 years** in the Chi River Basin in relation to water resources and water use, e**.**g**.** increase in the population, tourists, factories and agricultural areas, as well as climate change**.**

2.1) Population – In 2017, the Chi River Basin had a population of 5,953,334 (5.95 million) and it is expected to reach 6,386,218 (6.38 million) in 2037.

2.2) Tourists – This year, the local area was visited by 4,267,102 (4.27 million) tourists, which is forecast to increase to 8,975,513 (8.98 million) in 20 years.

2**.**3) Industry – Currently, there are 16,055 factories in the local area. Based on the GPP growth, it is expected that the industrial sector will enjoy 3.4-percent growth rate per year.

2.4) Agricultural areas – The Chi River Basin comprises agricultural areas spanning 20,436,852 rai (20.44 million rai), with irrigation areas and benefiting areas spanning 4,601,179 rai (4.60 million rai). Additional 4,949,136 rai (4.90 million rai) land has the potential to be developed to be new irrigation areas and benefiting areas. If the water source projects in the Chi River Basin are developed at their full potential, additional 2,887,380 rai (2.89 million rai) can be developed to be new irrigation areas and benefiting areas. If Mekong River diversion occurs, additional 2,061,756 rai (2.06 million rai) can be developed to be new irrigation areas and benefiting areas. The size of the expected new irrigation areas and benefiting areas will cover 9,550,315 rai (9.55 million rai).

2.5) Climate change – The study on the climate change reveals that the Chi River Basin will tend to have higher temperature, decreasing annual accumulative rainfall, decreasing runoff, and more serious water shortage in the future.

3) **Current and future water demand –** The assessment of current water demand considers different activities, e.g. domestic use, industry and tourism, agriculture, and livestock. The assessment in the next 20 years takes into account the increase in population and in the number of tourists in different provinces located in the Chi River Basin, urbanization, water demand in the agricultural and livestock sectors, and water demand in the industrial sector. The water demand in different cases – development of water source projects at their full potential and Mekong River diversion is assessed for various activities, as shown in **Table 8.1-1**.

Table 8.1-1 Assessment of Water Demand in Various Activities

Water use activity	Current condition (2019)		Future 20 years (2037)			
	Irrigation and benefiting areas (rai)	Water demand (MCM/year)	In case of water source project development in the Chi River Basin at full potential		In case of water source project development in the Chi River Basin at full potential and Mekong River diversion	
			Irrigation and benefiting areas (rai)	Water demand (MCM/year)	Irrigation and benefiting areas (rai)	Water demand (MCM/year)
1 Agriculture[1/]	4,601,179	4,899.66	7,488,559	7,822.73	9,550,315	12,193.69
2 Domestic use	-	125.67	-	129.11	-	129.11
3 Tourism	-	1.12	-	2.34	-	2.34
4 Industry	-	33.07	-	55.38	-	55.38
5 Livestock	-	9.16	-	15.92	-	15.92
Total[2/]	**4,601,179**	**5,068.67**	**7,488,559**	**8,025.48**	**9,550,315**	**12,396.44**

Remark : [1/] Water demand for agriculture : water flowing back is deducted.
[2/] Water for maintaining the ecosystem is water discharged from large-scale reservoirs, whereby water can be reused,
Source : Analyzed by the consultants, 2019

4) Water source projects and irrigation projects – Currently, there are 2,765 water source projects and irrigation projects located in the Chi River Basin area which are completed projects. They consist of large-, medium-, and small-scale water source projects and pumping projects. The main responsible agencies consist of the Royal Irrigation Department, the Department of Water Resources, and the Electricity Generating Authority of Thailand. Their total storage capacity is approximately 5,687.26 MCM, with irrigation area spanning approximately 3,446,187 rai (3.44 million rai) and benefiting areas spanning 1,154,992 rai (1.15 million rai).

5) Conditions of problems in the Chi River Basin area are outlined below:

5.1) Conditions of problems in the Chi River Basin area – Currently, the Chi River Basin area experiences the issues of flooding, drought and wastewater frequently, which have impacts on the living conditions and lead to a huge loss of incomes and property of local people each year, especially drought, which often occurs in the dry season of every year. This leads to connected socio-economic issues – low incomes earned by local farmers and people, labor migration, and average household income in the Chi River Basin area being lower than the country' s averages.

5.2) The conditions of the issues of drought, flooding and wastewater for the above reasons will be aggravated in the future due to the increase in population and in the number of tourists, urbanization, a lack of wastewater treatment sources, increase in water consumption for agriculture, as well as climate change, which causes the increase in temperatures and decrease in rainfall and runoff.

6) The selection of alternatives for the development of the Chi River Basin area to solve the issues of drought, flooding and water quality requires systematic planning for the development and integration of responsible agencies**.** The followings were five proposed alternatives for the development in the Chi River Basin to address these problems and ensure economic development:

Alternative 1: Business as usual – It is an alternative with no implementation of policy recommendations, plans or programs or no actions which are deviant from existing directions or guidelines.

Alternative 2: The development for basic necessities and development of sustainable agricultural areas – Supplying high-standard quality water for domestic use for living of local people; providing sufficient water bodies in rainfed agricultural areas to ensure self-dependence, conserving soils and rehabilitating watershed forests, reducing poverty in rural areas, and develop the Sufficiency Agriculture Model or the Khok Nong Na Model.

Alternative 3: The management of water resource-related risks at the area level and the development of related agricultural industries – Processing and adding the value to agricultural products, organic farming, and provision of water to support existing industries. This alternative aims to address the issues of drought, flood and wastewater, especially protection of floods in main cities to reduce the income gap between rural and urban people.

Alternative 4: The development of agroindustry in the northeast region – This focuses on water resource development at its full potential and provision of water to support new industries and tourism (ecotourism and prehistoric tourism). This alternative aims to increase the incomes of people in the river basin, reducing social inequality, and increase the GRP of the northeast region.

Alternative 5: **The development of business agriculture as the center of the Greater Mekong Subregion** – This alternative involves the diversion of water from the Mekong River to increase irrigated agricultural areas to respond to the expansion of all types of industries, create the stability and security of water for agriculture, especially in the dry season, and add the value of water in production (business agriculture and exportation), and increase the country's GDP.

Following the participation in selecting alternatives at the forum meeting among 10 water user groups in the Chi Sub-basin (covering 27 Chi sub-basins), nine groups selected Alternative 3 and only one group (Mueang District, Khon Kaen Province) selected Alternative 5. The selected alternative, which is suitable in the economic, social and environmental dimensions, is Alternative 5: The development of business agriculture as the center of the Greater Mekong Subregion. As it obtained the highest scores, it was selected to address these issues and develop the economy in the Chi River Basin area to ensure that local people enjoy prosperity and sustainable development**.** The development plans for Alternative 5 include the followings:

- Development which meets basic needs and ensures thorough development distribution.
- Environmental management for watershed forest conservation and rehabilitation.
- Management of the Chi River Basin area to solve the flooding, drought and wastewater issues.
- Economic development in the Chi River Basin area based on the potential of water in the Chi River Basin.
- Economic development by increasing water availability in the Chi River Basin to ensure water use stability.

7) Preparation of the Integrated Water Resource Development Plans – Based on the alterative development plans, the Strategic Plans for Integrated Water Resource Development were formulated, which took into account local needs identified in ten public hearing events held in the Chi River Basin area and suitability in the economic, social and environmental dimensions. They consist of short-, medium-, and long-term water resources development strategic plans, as outlined below:

7.1) The short-term (years 4-5) and medium-term program (years 6-10) of the National Strategic Plan – Goals to address **social and environmental** issues were set. To achieve Goals 1-3, Alternative 3 was defined as the program for the development of the Chi River Basin area in line with the demand of most participants in the public hearings, as follows:

(1) Basic Problem Solving Program, which consists of the provision of water for domestic use, local administrative organizations' water supply system improvement projects, local administrative organizations' water source development projects, management of rainfed agricultural areas, provision of water sources in rainfed agricultural areas, and recycling of treated used water and construction of watershed weirs.

(2) Drought, Flood and Wastewater Mitigation Program, consists of the enhancement of the efficiency of water use in irrigation areas; project improvement, maintenance and optimization; development of small-scale water source and pumping projects; flood protection, e.g. improvement of streams, drainage systems and waterway obstruction, development of monkey cheeks in lowland floodplain forests and prevention of bank erosion based on local needs.

7.2) Medium- (years 9-10) and long-term program (years 11-20) of the National Strategic Plan – This was set under Goals 4 and 5. Alternative 5 was proposed for the development of the Chi River Basin area, which aims to increase income for people, create opportunities for economic development in the Chi River Basin area and nearby river basins, and provide water for agriculture, tourism, and industry to provide people in the Chi River Basin area with good quality of life and income stability, prosperity, and sustainability.

Water Source Project Development for Economic Development Program, consists of:

- Development of large- and medium-scale water source projects in the Chi River Basin area at their full potential, water conveyance systems, and domestic water networks.
- Increase of water in the Chi River Basin by diverting water in the Mekong River (Huai Luang Regulator)

8) Management – Currently, the Chi River Basin area experiences issues related to laws, laws, regulations, rules, and cooperation between government agencies and private organizations in water resources management, as follows:

8.1) Reservoir management.
8.2) Management of the PWA/local waterworks.
8.3) Delays of government agencies.
8.4) Soil from dredging.
8.5) Wastewater management.
8.6) Environmental management.
8.7) Development of data for decision-making.
8.8) Participation.

To ensure the efficiency and effectiveness in the management of the water resources issues, including drought, flooding and wastewater, improvements should be made in different areas, e.g. laws, regulations, knowledge provision, and participation.

9) Impacts, and impact mitigation and monitoring measures - implementation of the water resource development plans in the Chi River Basin leads to the following positive and negative impacts:

9.1) Positive impacts bring about benefits from development, e.g. clean and good quality water, ecology maintenance, water sources within rainfed agricultural areas, more efficient water distribution, increased areas of cultivation in both wet and dry seasons, solutions to wastewater problems, reductions in water loss due to floods, increased water storage because of the development of medium- and large- scale water sources, and increasing water availability in the Chi River Basin.

9.2) Negative impacts, e.g. impacts on conservation forests, farmers' learning and adjustment costs for cultivation, farmland and residential areas, soil disposal areas related to irrigation canal dredging and high budgets.

9.3) Impact mitigation measures: Relevant agencies shall create an understanding among local people and responsible people, plant forests twice the amount of lost forests as defined by law, pay fair compensation and prepare and improve disposal areas in accordance with ecosystems.

9.4) Monitoring measures: To make the operation according to water resource development plans in the Chi River Basin achieve the development goals, the monitoring measures in the three dimensions must be carried out:

(1) Economic: income, unemployment and labor migration
(2) Social: compensation, people affected remedy and chemical risk monitoring
(3) Environmental: reforestation, land use, water quality and organic famring

10) Integration of Chi River Basin development plans to be a center of the Greater Mekong Subregion – The development plans for water resources in the Chi River Basin involve provision of sufficient, secure and stable water to support and provide an opportunity for economic development comprising: 1) basic problem-solving, 2) drought, flood and wastewater mitigation program, and 3) water source project development for economic development program. They include water source project development of the Chi River Basin at full potential and Mekong River diversion to support plans for developing the Chi River Basin area to be a center of the Greater Mekong Subregion. The strategic plans for water resource management must be integrated with the Chi River Basin development plans as follows:

10.1) Transport and logistics development plans
10.2) Agricultural business development plans
10.3) City and tourism development plans

11) Driving plans into practice – The ONWR is a major agency to drive the development plans for water resources in the Chi River Basin continuously and seriously by integrating the strategic plans with Chi River Basin development plans of different agencies to develop the Chi River Basin to be the center of the Greater Mekong Subregion. The ONWR must formulate the plans into practice as follows:

11.1) Proposing the SEA/ SIDP to the River Basin Committee and all relevant sectors to share comments for the ONWR to screen and present to the National Water Resources Committee and the Cabinet, respectively.

11.2) Driving the development plans for water resources in the Chi River Basin requires implementation of the above six steps. The key component is the clarity of the programs/projects under the six aspects in relation to coordination and integration of work between responsible agencies, impact assessment and monitoring, implementation assessment and monitoring, and adjustment of plans in lien with existing situations and problems.

11.3) Managing big data to be used for systematic water resource management comprises three components, namely (1) water resource data systems (2) supporting components, e.g. participatory networks, agencies and development plans in the river basin, information systems to support water resource management and (3) laws and regulations for water resource management.

11.4) Managing big data on water resources, which is in line with the new approach to public administration to gear towards a high performance organization, i.e. competent managers, skilled knowledge workers, efficient and strong work systems, and knowledge management.

8.2 Recommendations

As for the Chi River Basin Strategic Environmental Assessment, the optimal alternative was selected for the Chi River Basin development. To ensure the implementation of the Plan for the Integrated Development of Water Resources in the River Basin, the ONWR should take actions, as presented in **Table 8.2-1**, as follows:

1) Request for the project approval.
2) Driving for practical results at the policy and area levels.
3) Implementation of the Plans for the Integrated Development of Water Resources in the Chi River Basin at the policy and area levels.
4) Management – The ONWR must coordinate with agencies concerned, set up committees and subcommittees at different levels. The implementation guidelines for management of each aspect are presented in **Table 8.2-2**.
5) The implementation monitoring measures must be implemented by the ONWR, which must coordinate with other responsible agencies to monitor and evaluate activities to ensure that their objectives are achieved and to assess the benefits and adverse effects based on the economic, social and environmental indicators throughout the implementation period, as presented in **Table 8.2-3**.
6) Formulate the Chi River Basin Development Policy to be the center of the Greater Mekong Subregion. The ONWR must carry out the Water Resource Management Plan in the Chi River Basin and act as an agency that coordinates with various agencies, including integrating the Chi Basin Development Plan in various fields to develop the Chi Basin area as the center of the Greater Mekong Subregion.

Table 8.2-1 Results and Recommendations for Driving the Development Plans for the Integrated Development of Water Resources in the Chi River Basin under the Chi River Basin Strategic Environmental Assessment

No	Plan	Target	Recommendations	Driving
1.	**Basic Problem Solving Program** Aspect 1: Consumption-based water management 1.1 Consumption-based water provision 1.2 Local administrative organizations' water supply system improvement projects 1.3 Local administrative organizations' water source development projects Aspect 2: Water security creation in the manufacturing sector. 2.1 Management of rainfed agricultural areas. 1) Cropping to suit the areas 2) Economic forestation (rai) 2.2 Provision of water sources in rainfed agricultural areas. Aspect 4: Water quality management and water resource conservation. 4.1 Recycling of treated used water. Aspect 5: Conservation and rehabilitation of degraded watershed forests and soil erosion. 5.1 Forestation (rai) 5.2 Watershed weirs (permanent weirs) Aspect 6: Management. 2. **Drought and Flood Mitigation Program** Aspect 2: Water security creation in the manufacturing sector. 2.1 Enhancement of the efficiency of water use in irrigation areas. 2.2 Project improvement, maintenance and optimization. 2.3 Development of small-scale water source and electrical pumping projects. Aspect 3: Management of flood. 3.1 Flood protection, e.g. improvement of streams, drainage systems and waterway obstruction 3.2 Prevention of bank erosion based on local needs. 3.3 Development of monkey cheeks in lowland floodplain forest areas. 3.4 Floodways 3.5 Flood protection in urban communities 3.6 Water diversion to solve floods Aspect 4: Water quality management and water resource conservation. 4.1 Wastewater solution Aspect 6: Management. 3. **Water Source Project Development for Economic Development Program** Aspect 2: Water security creation in the manufacturing sector. 2.1 Development of water source projects at their full potential. Development of medium- and large-scale water bodies. Development of water distribution systems. Development of domestic water networks. 2.2 Increase of water in the Chi River Basin by diverting water from the Mekong River. Aspect 6: Management.	**Environmental dimension** 1. The existing forest areas span 5.09 million rai, representing 16.58 percent of the river basin area. This will increase the watershed forest areas in conservation forests to 831,406 rai, representing 2.71 percent. 2. A 66,062-rai increase for economic forests. 3. Reduction in the wastewater issue in the Phong River and Chi River. **Social dimension** 1. Standard-quality water for domestic use in all villages. 2. The 20.44 million rai agricultural areas in the Chi River Basin, which are mostly rainfed agricultural areas, will benefit from the development of small-scale water bodies in farms and soil development-related knowledge. 3. 4,040 farmer households in rainfed agricultural areas will be beneficiaries. 4. 192,837 farmer households will earn more incomes from the development of rainfed agricultural areas to be irrigation areas and beneficiary areas from 4.60 million rai to 9.55 million rai. 5. Reduction in the loss of farmland and residential areas through erosion protection. 6. Mitigated urban flooding. **Economic dimension** 1. 2.15-percent increase in the gross provincial product in the Chi River Basin. 2. Proportional income distribution: 63.68 percent for the rural population and 36.62 percent for the urban population. 3. Value added to water in production.	**1. Policy level** 1.1 Request for the approval of the Chi River Basin Strategic Environmental Assessment, which involves: Short- and medium-term programs for alternative development to solve social and environmental problems (1-10 years): - The Basic Problem-Solving Program. - The Medium- and Long-term Drought and Flood Mitigation Program. and the Water Source Project Development for Economic Development Program (Long term: 6-20 years) - Development of medium- and large-scale water bodies. - Development of water distribution systems. - Development of domestic water networks. - Development of the Mekong River diversion. 1.2 Development of the strategic plans in line with types of water resources in accordance with the Water Resources Act, B.E 2561 (2018). **Type 1** Domestic use Subsistence farming Household industry Ecology maintanance Responsible by: public agencies/local administrative organizations Proposed to: The ONWR according to the National Water Resources Committee's approval **Type 2** Industry Tourism industry Electrical power Waterworks and other activities Responsible by: public agencies/local administrative organizations Must be approved by the director-generals of relevant departments Proposed to: The ONWR according to the River Basin Committee's approval **Type 3** Large-scale business Interbasin Area coverage Responsible by: public agencies/local administrative organizations Must be approved by the director-generals of relevant Proposed to: The ONWR according to the National Water Resources Committee's approval **2. Area level** 2.1 Creation of social participation in ecosystem conservation in the Phong River in the industrial sector and local administration in the management of wastewater from its sources and provision of the agricultural learning process system, including agriculture and fish ponds. 2.2 Establishment of an early warning system to raise local awareness of ecosystem conservation among local people, and prevision of a news communication system to allow the general public to be aware of ecological problems thoroughly. 2.3 Advising the local industrial sector and public administration sector to provide the water reserve system to solve the drought issue and advising local farmers to provide ponds in their farms to solve the problem. 2.4 Establishment of the water management system in accordance with the Water Resources Act. B.E. 2561 (2018) From the field study, under Section 5 (Paragraph two), Section 17 (7), Section 40 and Section 48, which authorizes the National Water Resources Committee to take the action. 2.5 Management of agricultural products to add their value by optimizing the supply chains and logistics efficient and make them meet customer needs, as follows: 1) Establishment of the product quantity and quality network, 2) Logistics channels, 3) Marketing channels, and 4) Accurate knowledge. 2.6 Creation of knowledge of participation in, and awareness of, water pollution management. 2.7 Coordination with different agencies to improve programs/projects in line with situations and achieve the set goals. 2.8 Implementation supervision and monitoring. 2.9 Program and project evaluation.	To drive the Chi River Basin Strategic Environmental Assessment, this should be implemented: 1. Coordination of cooperation and creation of an understanding with different related agencies. 2. Cooperation with responsible agencies to improve programs/projects to solve problems in the five areas in the Chi River Basin in accordance with people's need. 3. Creation an understanding with the River Basin Committee and local people. 4. Request for the approval of the program/project framework to drive them into execution. 5. Coordination with responsible agencies to accelerate program/project implementation in the Basic Problem Solving Program . 6. Acceleration of the implementation the Project's programs proposed based on the Guidelines for the Integrated Development of Water Resources in the Chi River Basin. 7. The Mekong diversion involves comparing alternatives to select the optimal alternative in engineering, economic, social and environmental terms for feasibility study and environmental impact assessment. 8. Implementation supervision and monitoring. 9. Program and project evaluation.

Source : Analyzed by the consultants, 2019

Table 8.2-2 Recommendations for Management

Management	Implementation guidelines	Agencies in charge
1. Water management	1.1 Establishing the Committee on water management at the river basin and large-scale reservoir levels and the Subcommittee/Committee for managing medium-scale reservoirs at the provincial level which have the capacity exceeding 20 MCM, with the Office of the National Water Resources coordinating with different relevant agencies to plan the use of water for different activities in line with water availability and conduct water use evaluation and monitoring. 1.2 Promoting knowledge among farmers, farmer groups, big plot farmland, network agriculture, new theory agriculture, cultivation of low water use economic crops, logistics management, marketing channels, etc. 1.3 Engaging farmers with the Royal Irrigation Department in water use planning and water allocation at the project level. 1.4 Installing automated water delivery equipment at different control structures to ensure efficient water management.	The ONWR coordinates with the EGAT, the Royal Irrigation Department and local farmer groups.
2. Management of water for domestic use	2.1 Promoting the expansion of the PWA's waterworks service areas, providing water supply reserved sources, and managing water loss. 2.2 Agencies under local administrative organizations responsible for waterworks management should: - Establish the Village Waterworks Data Center at the Office of National Water Resources. - Promoting academic support and providing budget for training relevant personnel to equip them with knowledge and expertise, which allows for their efficient management. -Setting the standard for village waterworks and assessing the levels of village waterworks quality at least once a year.	The ONWR coordinates with Provincial Waterworks Authority and local administrative organizations.
3. Management of materials from dredging	Managing materials from dredging (gravel, stone, soil, sand) and dredging water bodies under the authority of the Ministry of Interior and the Marine Department. The materials obtained from dredging (gravel, stone, soil, and sand) should be managed as follows: 1) In case a budget is used for hiring, comply with the Office of the Prime Minister's Regulation on Supplies or the Ministry of Interior's Regulations on Supplies of Local Public Administration Entities The project owner agency is allowed to use the gravel, stone, soil, and sand from dredging for public interest. (as implied in Section 6 of the Regulations). 2) In case no budget is used, comply with the Office of the Prime Minister's Regulations on Supplies or the Ministry of Interior's Regulations on Supplies of Local Public Administration Entities. The wage must be in the form of gravel, stone, soil, and sand instead of budget monies. The project owner agency appraises the wage in the amount under its authority to compare the quantity the gravel, stones, soil, and sand to pay instead of a wage. To valuate the gravel, stone, soil, and sand as a wage, do calculation based on the compensation for licensing under the implication of Section 9 bis of the Land Code in the Compensation Account enclosed to the Land Code mutatis mutandis (no more than 28 baht per m^3). Deduct the wage from the price of the gravel, stone, soil, and sand. If the gravel, stone, sand, and soil is worth more than the wage, ask the dredger to pay for the excess compensation for the gravel, stones, soil, and sand to the government. That money becomes a revenue of that local government organization (in accordance with the implication of Section 6 of the Regulations). Dredging of water bodies in the State Land is under the authority of the Ministry of Finance, such as irrigation areas or irrigation waterways under the Royal Irrigation Act. The materials from dredging (gravel, stone, soil, and sand) must be managed as follows: (1) As for the amount of soil or other materials obtained from the State Land, comply with the Office of the Prime Minister's Regulations on Supplies mutatis mutandis (according to the implication of the Regulations, Volume 1, Section 22). (2) As for the valuation of the dredging cost, if the appraised cost exceeds the wage, the contractor must pay for the excess compensation for the gravel, stones, soil, and sand to the government, and the user of the State Land shall send that excess compensation to the Treasury as a revenue. (3) Spend that money for public interest (According to implication of the Regulations, Volume 1, Sections 23-27).	The ONWR coordinates with the Ministry of Interior, local administrative organizations and relevant agencies.
4. Wastewater management	1) Industrial wastewater management 1.1) Factories must comply with the regulations, rules and laws on disposal of pollution and wastewater from the factories' production process. 1.2) Measuring the quality of water in the rivers located near the factories. 1.3) Regularly monitoring wastewater discharged from factories and strictly complying with law in case water pollution results from wastewater discharged from the factories. 1.4) Engaging representatives of members of communities near factories as members of the Factory Wastewater Inspection Committee. 2) Municipal wastewater management 2.1) Raising the awareness of, and campaigning for, throwing no litter or sewage to water bodies or nearby areas to pollute water, among urban residents. 2.2) Assigning relevant local agencies to carry out solid waste disposal in conformity to academic principles. 2.3) Constructing wastewater treatment sites in urban communities. 2.4) Monitoring the quality of water in urban water bodies. 3) Agricultural wastewater management 3.1) Educating farmers about utilization of chemical fertilizers and advising them not to use chemical fertilizers that result in water pollution. 3.2) Examining the quality of water released from agricultural areas.	The ONWR, Pollution Control Department, and local administrative organizations.

Table 8.2-2 Recommendations for Management (Cont'd)

Management	Implementation guidelines	Agencies in charge
	4) Management of wastewater from caged fish culture. 4.1) Defining control areas for caged fish culture as areas with all-year-round water availability which can release water to dilute wastewater. 4.2) Promoting and educating about caged fish culture practices that cause no water pollution.	
5. Environmental management	1) Forest resources 1.1) Defining the clear boundaries of legal forests to prevent forest encroachment and reduce conflicts with people. 1.2) Carrying out campaigns and public relations which ensure degraded watershed forest conservation and restoration and soil erosion prevention. 1.3) Encouraging communities to participate in management for conservation, rehabilitation and sustainable use of forests. 1.4) Promoting planting economic trees in both forest areas and private areas to increase forest areas and generate communality incomes. 2) Water quality 2.1) Promoting management of municipal and industrial wastewater to reduce and control the discharge of pollutants from designated sources into water bodies. 2.2) Promoting the establishment of networks in all sectors for surveillance and monitoring of water pollution sources 2.3) Encouraging the private sector and different agencies to carry out campaigns and public relations which equip the general public and entrepreneurs are equipped with knowledge and understanding and share the responsibility for managing water quality and controlling wastewater from its sources. 2.4) Defining areas of aquaculture and caged fish culture in an appropriate amount. 2.5) Improving the efficiency of monitoring and strictly enforcing laws to ensure discharged wastewater meets specified standards. 2.6) Developing a database on pollution sources and the amount of wastewater discharged from its sources to water bodies. 3) Soil and agricultural resources 3.1) Promoting a reduction in utilization of chemicals and campaigning for organic farming to benefit from natural resources in a sustainable manner. 3.2) Rehabilitating and improving problematic and degraded soils so that they have good quality to ensure proper utilization.	The ONWR coordinates and collaborates with the Department of National Parks, Wildlife and Plant Conservation, and the Pollution Control Department.
6. Data development for decision-making.	1) Different agencies must have data on the same base and which is updated, e.g. maps with the same scale showing different land use types, contour lines, project data, meteo-hydrological data, socio-economic data, etc. 2) Data possessed by different agencies which share the same system and are interoperated quickly and efficiently . 3) Data systems can be analyzed on a real time basis to support decision making to ensure a right decision is made on resolving problems in line with existing situations.	The ONWR is the main agency for the implementation.
7. Participation	1) Policy level 1.1) Appointing a working group to jointly formulate appropriate policies in line with current conditions and future trends. 1.2) Monitoring implementation results on a continuous basis. 2) Program level 2.1) Appointing a working group for each mission to translate policies into plans and programs and inviting representatives of people from local areas or communities to share opinions and jointly develop plans and programs on relevant issues. 2.2) Scheduling joint meetings to carry out planning and monitor implementation results on a continual basis until the missions are completed. 2.3) Involving representatives of the general public to acknowledge and reflect on the current conditions of the areas before the development of programs to ensure that they are appropriate, e.g. planning water allocation for agriculture, planning dredging water bodies, and planning resource management. 3) Project or operational levels 3.1) Establishing groups/organizations in a systematic manner to strengthen local communities, e.g. the Farmers Group, Water Users Group, and the Resource Conservation Group. 3.2) Jointly planning the implementation of activities in the local areas, e.g. setting the time for opening-closing the regulators and monitor operations. 3.3) Holding meetings to learn about project details at the area level and different problems to identify solutions together.	The ONWR is the main agency in the implementation.

Table 8.2-3 Measures for Monitoring the Implementation of the Development Plans for the Water Resources in the Chi River Basin

Economic, social and environmental dimensions	Implementation guidelines	Objectives	Indexes	Implementation period			Responsible agencies
				Short-term (Years 4-5)	Medium-term (Years 6-10)	Long-term (Years 11-20)	
Economic dimension **Goals of Chi River Basin development** **Stable economic development** **to increase the income and quality** **of life of people**	1. Monitoring and assessing the income of people in the Chi River Basin area.	To assess the distribution of people's income after the development of the Development Plans for Water Resources in the Chi River Basin.	GPP per capita (baht/person/year).	/	/	/	The Office of the National Economic and Social Development Council (NESDC)
	2. Monitoring and assessing the unemployment and migration of workers in the Chi River Basin area.	To assess the distribution of people's income after the development of the Development Plans for Water Resources in the Chi River Basin.	Rate of unemployment and migration of workers out of their community.	/	/	/	The Ministry of Labor (Department of Employment)
	3. Monitoring and evaluating the promotion of low-water use plants and economic crops among farmers.	To encourage farmers to cultivate low water use plants and economic crops to add the value to their products.	Household income.	/	/	/	The Ministry of Agriculture and Cooperatives (Office of Agricultural Economics)
Social dimension **Goals of Chi River Basin development** **Distribute development throughly** **and provide peoples' access to water**	1. Monitoring the efficiency of the village waterworks.	To evaluate the efficiency of village waterworks service.	Proportion of the population with water access	/			The Ministry of Interior (Local administrative organizations)
	2. Monitoring the efficiency of the waterworks in urban communities and economic areas.	To evaluate the efficiency of village waterworks service in urban areas and economic areas.	Proportion of the population with water access.	/			The Ministry of Interior (The Provincial Waterworks Authority).
	3. Monitoring and evaluating the efficiency of water management jointly carried out by government agencies and all relevant sectors.	To evaluate the effectiveness of water management jointly carried out by government agencies and all relevant sectors.	Reduced water use conflict and thorough water distribution.	/	/	/	The Ministry of Agriculture and Cooperatives (The Royal Irrigation Department) The Ministry of Natural Resources and Environment (The Department of Water Resources, and the Department of Groundwater Resources) The Ministry of Interior (Local administrative organizations)
	4. Monitoring the provision of compensation and remedy for affected persons.	To evaluate the provision of compensation and remedy for persons affected by the development based on the Development Plans for Water Resources in the Chi River Basin	Number of affected households.	/	/	/	The Ministry of Agriculture and Cooperatives (The Royal Irrigation Department) The Ministry of Natural Resources and Environment (The Department of Water Resources, and the Department of Groundwater Resources) The Ministry of Interior (Department of Public Works and Town & Country Planning)
	5. Monitoring the risks of chemical exposure.	To evaluate health risks of farmers and the general public.	Rate of illness due to chemical contact.	/	/	/	The Ministry of Public Health (The Department of Disease Control)
Environmental dimension **Goals of Chi River Basin development** **Development for balanced environment** **through protection, treatment and** **rehabilitation of natural resources** **and the environment**	1. Monitoring and evaluating growing lowland floodplain forests in the watershed forest areas.	To evaluate the efficiency of conservation and rehabilitation of watershed forests and the ecosystem of watershed areas.	Percentage of forest areas.	/	/		The Ministry of Natural Resources and Environment (The Royal Forest Department and the Department of National Parks, Wildlife and Plant Conservation)
	2. Monitoring the change in land use in accordance with the town planning law based on the potential of natural resources and the environment.	To prevent encroachment of forest areas in conservation areas.	Percentage of holding each type of land compared with the Chi River Basin area.	/	/	/	The Ministry of Natural Resources and Environment (The Royal Forest Department and the Department of National Parks, Wildlife and Plant Conservation) The Ministry of Agriculture and Cooperatives (The Land Development Department and the Office of Agricultural Land Reform Office). The Ministry of Interior (Department of Public Works and Town & Country Planning and the Department of Lands)
	3. Monitoring the quality of water in natural water bodies with wastewater treatment.	To monitor the quality of water in natural water bodies.	Good water quality (Water Quality Criteria or WQI)	/	/	/	The Ministry of Natural Resources and Environment (The Pollution Control Department)
	4. Monitoring the quality of water after being treated by establishments.	To monitor the quality of water after being treated by establishments.	Criteria for the quality of wastewater from factories.	/	/	/	The Ministry of Industry (The Department of Industrial Works)
	5. Monitoring the efficiency of the central wastewater treatment system of community and urban areas.	To inspect the efficiency of functioning of the central wastewater treatment system of communities and urban areas.	Criteria for controlling wastewater dischargesd from municipal wastewater treatment systems	/	/	/	The Ministry of Natural Resources and Environment (The Pollution Control Department)
	6. Monitoring and being strict with law enforcement to ensure that wastewater drainage meets specified standards.	To ensure that establishments comply with law on wastewater treatment.	Proportion of complaints processed.	/	/	/	The Ministry of Industry (The Department of Industrial Works)
	7. Monitoring and evaluating the promotion of organic farming.	To reduce the amount of chemical use and reduce contamination to the environment, farmers, and consumers.	Percentage of organic farming areas.	/	/		The Ministry of Agriculture and Cooperatives (The Department of Agricultural Extension)