I, Yuwadee Ongkosit, hereby submit this original work as part of the requirements for the degree of Master of Community Planning in Community Planning.

It is entitled:
An Integrated Land Use and Water Plan for Mahasarakham Province, Thailand

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Committee member: Christopher Auffrey, Ph.D.
An Integrated Land Use and Water Plan for Mahasarakham Province, Thailand

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Abstract

This thesis identifies water-related problems that Mahasarakham Province, Thailand faces and the correlation between water and land use. Natural hazards are inevitable, and they ruin properties and cause changes to natural features. Two ways that the Thai government acts to mitigate their impact is to create or implement both structural and non-structural plans, but it heavily focuses on the first. The structural measures do not always relieve water-related problems. However, the non-structural measures can at least mitigate the effects posed on water resources. Land use and water resources are interconnected. One cannot separate one from another. Thus, this thesis also proposes an integrated water and land use plan that regulates the patterns of land use and prohibit certain uses at the national and local level. The proposed plan will help people better understand the interaction of land use and water resources.
## Table of Contents

Chapter 1: Introduction 1
Chapter 2: Literature Review 14
Chapter 3: Methodology 26
    Research Design 26
    Instrumentation and Data Collection 27
Existing Plans 28
    National Level Plan and Action 28
    Regional Level Plan and Action 35
    Provincial Group Plan and Action 41
    Provincial Level Plan and Action 41
    Local Level Plan and Action 44
An All-Scale Framework of Planning Policy in Mahasarakham Province 46
Chapter 4: Data Analysis and Findings 49
    Comprehensive Plans 49
    Population Growth Projection 57
    GIS Analysis 65
Chapter 5: Discussion & Conclusion 82
    National Level 82
    Local Level 85
Bibliography 90
List of Figures and Tables

**Figure 1** Locations of Thailand, the Northeastern Region of Thailand and Mahasarakham Province 4
**Figure 2** The Chi River 7
**Figure 3** National Water Resources Committee (NWRC) 17
**Figure 4** Locations of Thailand, the Chi Watersheds and the Fourth Part of Lam Nam Chi Watershed 23
**Figure 5** Zoning Map for Tha Khon Yang -Kham Riang Districts 50
**Figure 6** Zoning Map in Mueang Mahasarakham Plan 52
**Figure 10** Land Cover Map of the Fourth Part of Lam Nam Chi Watershed 66
**Figure 11** Soil of the Fourth Part of Lam Nam Chi Watershed 68
**Figure 13** Land Suitability for Rice Growing in the Fourth Part of Lam Nam Chi Watershed 71
**Figure 14** Soil of the Fourth Part of Lam Nam Chi Watershed 74
**Figure 15** Stream Order of the Fourth Part of Lam Nam Chi Watershed 76
**Figure 16** Floods in 2007-2011 79-81

**Table 1** Main Watershed in Thailand 22
**Table 2** Sub-watersheds within the Chi Watershed 24
**Table 3** Strategic Plan 40
**Table 4** Summary of Water-Related Plan 46-47
**Table 5** Zoning on Housing 53
**Table 6** Tiered Approach 57
**Table 7 and Figure 7** Population Growth Projection of Mahasarakham Province 59
**Table 8 and Figure 8** Population Growth Projection of Mueang Mahasarakham District 60
**Table 9 and Figure 9** Population Growth Projection of Kantarawichai District 61
**Table 10** Estimated Number of Students at Mahasarakham University 62
**Table 11** Economic Assumption and Estimation of Mahasarakham in 2012 and 2013 64
**Table 12** Soil Map Explanation 69
**Table 13 and Figure 12** Total Area and Percentage of Each Type of Soil Group 70
**Table 14** Land Capability Classification 72
Chapter 1: Introduction

Thailand is a major agricultural goods producer and exporter; thus, it is greatly concerned about water management, and it heavily focuses on structural approaches by building many dams, levees, floodwalls, water channels, etc. These human-made structures help in controlling the amount of water which is used in the agricultural sector, but they also pose a negative impact on the environment and change the natural flow of the surface water.

In 2008, the Northeastern Region of Thailand contains around 21 million acres, which accounts for 47.1 percent of Thai agricultural land.¹ Most of the region is located on a flat plain about 150 – 250 meters above sea level, which is suitable for agriculture. There are three main watersheds in this region, namely the Mekong, Mun, and Chi Watersheds, all of which have a combined area of around 41 million acres; but only 23 million acres can be used for agricultural purposes. The irrigation area accounts for just 10.27% of total agricultural land. The other 89.73% have to rely on rainfall for food production and annually encounter flood and drought. Even though Northeastern Thailand’s average rainfall is medium, it is not evenly distributed across the region. While the Mekong Watershed has high-intensity rainfall, there are not enough reservoirs to store water. In contrast, the upper part of the Mun, and Chi Watersheds have hilly topography, which is considered good for siting dams, but they have a low-rate of rainfall, and there are many limitations on developing the watersheds as there are many stakeholders. In the middle and lower parts of the watersheds lies a flat plain, which faces flooding or intermittent rain during the rainy season and drought during the dry season. There is lower production in the non-irrigated area than in the irrigated area. Due to unbalanced rainfall, farmers in Northeastern Thailand have low

¹ "More than 2.7 Million People Isan People Doing Agriculture," 2010.
crop yields and, in turn, have a median income lower than the national average. The Northeastern region contains around 65 percent of all the least well-off farm households in Thailand.²

To solve water problems in the dry season, the government launched the 1992 – 2033 Mekong-Chi-Mun Transbasin Irrigation Long-Range Project in 1992 to transfer water from the Mekong River to the Chi and Mun Rivers by using the gravity principle so that in dry season farmers have enough water to grow crops. It is estimated that the project can create around 1,968,936 acres of irrigated land. In the first phase, from 1992 to 2000, six small dams were built in the Chi Watershed, namely, the Chonnabot in Khon Kaen Province, Wang Yang and Khui Chuak in Mahasarakham Province, Roi-Et in Roi-Et Province, Yasothon-Pranompai in Yasothon Province, and Thatnoi in Ubonratchatani Province.³ Even if these small dams benefit local people in the Chi Watershed in the dry season, they pose a negative impact on agricultural land, on the way local people live, and cause changes in flow patterns of the Chi River, and, in turn, changes in its ecosystem.

Although a dam slows down the flow of the river, it cannot prevent flash floods and instead causes water to swamp affected land for a long period of time. In 2005, people affected by flooding in the Chi River Watershed gathered and asked the Royal Irrigation Department to open the dam gates during rainy season, from May to October, and it agreed to do so. Consequently, people did not encounter floods that year.⁴ To make room for development of the dams, many people have had to lose their land to be part of the dams and their basins.⁵ Most fish are unable

² Irrigation Project, Royal Irrigation," n.d.
³ Regional Office7, Royal Irrigation,"n.d.
⁴ Srimora, n.d.
⁵ "Asking the Government to Solve Mekong-Chi-Mun Project Problem," n.d.
to go upstream to lay eggs or go to their feeding grounds, causing reduction in their population. On top of that, potentially more salt may spread into the groundwater as a result of building dams in saline areas.\textsuperscript{6}

From the above explanation, it can be concluded that the structural approaches do not guarantee that dams can stop land from being flooded or can provide ample water for all populations. However, the combination of structural and nonstructural approaches together should be the best way to help cities manage water more effectively and efficiently.

The nonstructural approaches emphasize land use planning and the vegetation method such as agroforestry and soil conservation practices. The idea behind the approaches is that there is a relationship between land use and both surface and underground water. Human activities upstream affect the quantity and quality of water downstream, and, also, the timing of flow.\textsuperscript{7} Hence, to reduce those effects, it is crucial to take the whole Chi River Watershed into consideration, while making a watershed plan, even if the watershed sometimes goes beyond political boundaries. The plan can be effective, moreover, only when the institutional mechanisms have all the information about how the soil, water and biophysical resources are related.

Given the constraints of time and resources, however, this thesis will center on the Chi Watershed within Mahasarakham Province, and propose an integrated water and land use plan.

\textsuperscript{6} Buangam, 2008.
\textsuperscript{7} Gregersen et al., 2007, 22-23.
for Mahasarakham Province alone. Below, then, is information on Mahasarakham and details on what it has faced due to the misuse of water resources and the failure of water management.

Figure 1: Locations of Thailand, the Northeastern Region of Thailand and Mahasarakham Province

Mahasarakham is one of the provinces in the northeast part of Thailand, with an area of 2,043.112 square miles, which is bounded by Khon Kaen and Kalasin Provinces to the north, Surin and Buriram Provinces to the south, Kalasin and Roi Et Provinces to the east, and Khon Kaen and Buriram Provinces to the west.

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8 Data Source: Department of Provincial Administration, Ministry of Interior
9 "General Information of Mahasarakham Province." 2012, 2.
Mahasarakham means Village of a big Sal tree. The province is comprised of 13 districts: Mueang Maha Sarakham, Kae Dam, Kosum Phisai, Kantharawichai, Chiang Yuen, Borabue, Na Chueak, Phayakkhaphum Phisai, Wapi Pathum, Na Dun, Yang Sisurat, Kut Rang, and Chuen Chom districts and the districts are aggregated of 124 subdistrict administrative organizations and 18 municipalities and 1,944 villages.  

Mahasarakham lies on a plain of undulating and rolling areas with an elevation of 130-230 meters above sea level without major hills or mountains. Some parts of it are located on the Chi River Plain, which is one of the best rice growing areas in Thailand.

It is known that soils in the central, southern and western parts of Mahasarakham are infertile because they have a component of either salt or sand. There are around 67,000 acres of land with salt stain between 1-10% of total area in Phayakkhaphum Phisai District, and 67,000 acres of land with salt stain of more than 10% of total area in Wapi Pathum District. This leads to the simple conclusion that about 30 percent of Mahasarakham land is affected by salinity. In addition, there are 460,000 acres of sandy soils, which account for 35 percent, or a little bit more than one-third of the total land area of Mahasarakham. The sandy soils are not suitable for growing local crops because they drain quickly and do not hold water. Combining the two, 30 and 35%, we get a total figure of 65% of Mahasarakham’s land that are infertile, either from sandy or salty soils.

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Mahasarakham has a Tropical Monsoon Climate. The rainy season is from May to October, and the dry season is from November to April.\textsuperscript{13} In dry season, water is scarce in some areas, so underground water is common and widely used to satisfy the water needs of the population. However, using too much underground water results in increasing the levels of salt in surface water and soil. Thus, the land will end up with a higher salinity content and, at some point, this will cause the plants to wilt and die.\textsuperscript{14}

Mahasarakham’s predominant land use is agriculture, which accounted for 88.36\% of the total land use in 2011. The land is used for growing rice and other crops including cassava and factory sugar.\textsuperscript{15} Planning for water allocation is crucial because agriculture is the financial engine that drives Mahasarakham's economy. Thus, it has to create an effective water plan to bring supply and demand into balance. At present, the prices of all kinds of paddy rice are still high so Mahasarakham farmers tend to increase the area of their rice fields and move into the non-irrigated areas. They may encounter drought problems in the upcoming dry season, though, since there is no water management plan in place.\textsuperscript{16}

In addition, there are 10,479 surface water resources including ponds, swamps, brooks, and canals, most of which are located in Kosum Pisai, Borabue, and Mueang Mahasarakham

\textsuperscript{13} “General Information of Mahasarakham Province.” 2012, 2.
\textsuperscript{14} Provin and Pitt, 1914.
\textsuperscript{14} “General Information of Mahasarakham Province.” 2012, 11.
\textsuperscript{15} “Planting Double-Crop in Central Isan,” 2012.
\textsuperscript{16} “Mahasarakham Geography,” n.d.
Districts. There are also 1,325 ground water wells to supply the public, and 12 creeks, but most of these have supply problems due to loss of depth.\textsuperscript{17}

\textbf{Figure 2: The Chi Watershed}\textsuperscript{18}

The major surface water resource in Mahasarakham is the Chi River, 765 kilometers long, which originates from the Phetchabun Mountain Range in Chaiyaphum Province. The flow of the river is from many tributaries, including the Pong River at Khon Kaen Province, and runs through Mahasarakham from west to east, and then flows to Roi Et Province, before combining with the Mun River in Ubon Ratchathani Province.

\textsuperscript{18} Figure from Wikipedia, \textit{Chi River}, 2013. Modified by Yuwadee Ongkosit.
The Chi River is the main surface water resource of Mahasarakham and other provinces in Northeastern Thailand. Water from the Chi River is used for drinking and sanitation, and for growing rice, for orchards, for plants such as sugar cane, cassava and chili\(^{19}\), and for vegetables. It is also used for a hydroelectric power generation in Kon Kaen, by using high head water from the hydroelectric dam to drive a water turbine to provide a low cost of electricity. The dam itself functions as a huge storage facility collecting rain water during the rainy season and supplying water during the dry season.\(^{20}\)

The lack of water can impede the growth or expansion of Mahasarakham because water is really a vital component for living, as well as for agriculture and related industries. Thus, it is one of the most important keys to Mahasarakham’s future growth and economy.

However, Mahasarakham’s growth affects the Chi Watershed system and impairs the quality of surface and ground water. Hence, Mahasarakham needs a sustainable water plan to protect the Chi River and other water resources and to guide decision-making for the benefit of Mahasarakham and its current and future residents. Without good water planning, Mahasarakham may suffer severely from flooding and face water supply shortages and water pollution problems.

As the population in Mahasarakham grows, the demand for agricultural land will increase. More natural woodland is being replaced by agricultural and residential areas. Many farmers have grown paddy rice in the floodplain area because it is near the Chi River, with easy access to

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\(^{19}\) Ratanopad, and Kainz, 2006, 143.
\(^{20}\) The Public Relations Department of EGAT, n.d.
water supply and with high soil fertility. However, it is prone to flooding almost every year. Moreover, a lot of housing has been built near the banks of the Chi River in Kantharawichai District to accommodate students attending Mahasarakham University.21

Flooding is one of the frequent natural disasters experienced by people on the plains of the Chi Watershed in Mahasarakham and other provinces along the Chi River during the monsoon season. In September 2011, due to recurring rain, the Ubonrat Dam, which was built to prevent floods and store water for irrigation in Khon Kaen and Mahasarakham, was overfilled with excessive rainwater, and, to prevent any damage to the dam, a huge quantity of water was continuously released from the dam into the Chi River causing a rapid rise in the water level22 and then the flooding of the paddy fields and some residential areas in 6 sub-regions of Mahasarakham, such as Kosum Phisai, Chiang Yuen, Kantharawichai, and Mueang Maha Sarakham Districts23, even though it has 79 pumping stations, 18 medium-size dams, which together have a storage capacity of 81.570 million cubic meters, weirs, and 390 canals in Mahasarakham.24

The Department of Disaster Prevention and Mitigation of Mahasarakham reveals that in 2011, more than 280,000 people –more than 60% of Mahasarakham’s total population - have been impacted. 6,860 houses and 99,356 acres of agricultural land have been submerged.25 One reason is why there are so many people affected by this disaster is that some people live on the

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23 "Flooding in 6 sub-regions of mahasarakham," 2011.
24 Mahasarakham Provincial Official, n.d.
25 "Water Disaster Situation in Mahasarakham," 2011.
floodplain. The floodplain is considered by many as an appropriate area for agriculture, fisheries, and accommodation, but it has a high risk of being flooded.

However, flooding is not the only problem. Mahasarakham also faces a drought situation in the dry season every year. In first half of 2011, water levels in the dams in Mahasarakham, such as the ‘Wang Yang’ Weir collecting water from Chi River, had sharply decreased because of the lack of rain along with the hot summer weather. The drought caused damage to agricultural fields and farmlands in many districts, especially the areas that could not get access to water either from the surface water or from small dams, and many villages had water supply shortages.26 Because of the lack of a good water plan, Mahasarakham encountered water supply shortage problems.

In addition, the daily life of people in Mahasarakham also affects the quality of surface water and ground water. For an example, solid waste from residential and commercial areas, especially in Tha Khon Yang and Kham Riang Sub-Districts, which do not have centralized treatment plants, are released directly into the Chi River without any treatment. This nonpoint source pollution causes degradation of water and may affect plants and organisms, such as fish living in the Chi River and the people living downstream of the river.27

Moreover, demand for river sand, typically used to mix with aggregates for concrete work, has been increasing. More and more river sand is required for the highway and construction industries.

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26 “Drought in 13 Sub-Regions of Mahasarakham Has Damaged One Hundred Forty Thousand Rai of Rice Plantation,” 2011.
27 “Asking Residents to Conserve the Chi River,” 2010.
Licensed dredging areas in Mahasarakham typically lie at least twenty meters offshore, with an area of between 0.8 and 1.6 acres. Sand is dredged from the Chi riverbed by using a ship with 120-360 horsepower engines and is transported through pipes to the banks of the Chi River. Currently, eight dredging companies have received permission from Mahasarakham’s local government to dredge sand and gravel from the Chi River, seven of which are located in Mueang Maha Sarakham District, and the other one in Kosum Phisai District.28

Sand mining cause landslides along the Chi River banks and in other places that are not far from the sand deposits. This activity also causes changes in the river’s course and impairs the quality of water because sand and gravel flow and engine oil spills mix with the river water, and, dredging also causes noise pollution.29

However, Mahasarakham’s predominant land use is agriculture. Some farmers use chemical fertilizers and chemicals on their plants to help them grow. These chemicals can contribute to water degradation in both surface and underground water through runoff and the loss of soil fertility. In addition, fish farming cages in the Chi River also lead to water impairment by fish excrement and waste. Human activities cause pollutants in the river, which can harm people who use the polluted water.30 Thus, one can conclude that water and land use are closely related.

Not only is water planning absent, but land use planning in the province is scattered; that is, there is no Mahasarakham land use plan. Fortunately, Mahasarakham University recently signed a

29 "Asking Residents to Conserve the Chi River," 2010.
30 "Land Use and Water Quality," n.d.
contract with the province to prepare a regional development plan for Mahasarakham, and a water plan will be coordinated with this exercise.\textsuperscript{31}

In sum, water planning is crucial for Mahasarakham because it helps planners and the local government to find an efficient way to cope with flooding and reduce the duration of floods and the number of people or properties affected by it, as well as to satisfy water demands that come from its current and prospective residents, the agricultural sector, industries, and developers. Moreover, it also helps planners to explore a way to improve the quality of water resources in Mahasarakham. Finally, the land use plan and water plan should be interrelated.

The purpose of this study is threefold: (1) to find the underlining causes of flooding, drought and water pollution of the Chi Watershed; (2) to investigate the relationship between land and water of the Chi Watershed within Mahasarakham; and (3) to examine the land use and water planning of Mahasarakham and suggest an implementation plan linking the two. To achieve those goals, it is necessary to understand the previous and current situation of Mahasarakham by studying how land and water are linked together at the watershed level.

A watershed boundary, defined by natural hydrology and usually going beyond an administrative boundary, can help one understand how the ecosystem, geography, geology, and built-up features, all of which have an impact on land and surface and underground water, are interrelated.\textsuperscript{32} Without understanding the relationships between those aspects, it might be hard to

\textsuperscript{31} Tarawut Boonlua, February 1, 2012, e-mail message to David Edelman.
\textsuperscript{32} Randhir, 2007, 1,6.
find the real causes of problems and one cannot create an effective and comprehensive plan to solve the problems that people on the watershed have faced.

The structure of the rest of this thesis includes further discussion on the importance of studying water resources management at the watershed level, which is found in Chapter 2. This chapter reviews the relevant literature on watershed and integrated water resource management approaches that are used in dealing with unbalanced water resources and water degradation problems in Thailand.

Chapter 3 discusses the thesis methodology employed to assess the effectiveness of the current watershed plans and land use plans, and introduce the criteria used in the study.

Chapter 4 analyzes the information from published and online sources and fieldwork.

Finally, chapter 5 concludes the study with a recommendation for an integrated water and land use plan for Mahasarakham Province based on the analysis of Chapter 4.
Chapter 2: Literature Review

Clean water is one of the most important resources that people need to survive, but they require it in appropriate amount. Unbalanced water volume at one point can cause farmlands, residential, and commercial areas to be inundated, or land to be unproductive.\textsuperscript{33} To have a healthy watershed and reduce the impact of water-related disasters, good water management through an Integrated Water Resources Management (IWRM) approach for a watershed is needed.

The watershed approach is an appropriate framework that encourages cooperation among different groups of people in managing water resources. It has the goal to provide people with clean water from healthy watersheds.\textsuperscript{34} This approach leads people to look at every aspect: physical, organism, social and economic, that relates to it so that they can draft a plan that most people can benefit from, which has minimal negative effects on the environment and which makes agencies from the central and local governments, as well as businesses and local people, work in a coordinated manner within the same framework to find a solution that they can all agree upon. Thus, the plan can move forward without any interruption or conflicts. A sense of community is developed as local people work together to develop the plan, and they support it and do not try to stop some water development projects, as is currently the case, because they believe those projects cause negative changes in the watershed. Rather than using customary top-down planning, which often produces ineffective results; it is better to use a bottom-up approach because local people know their area best.\textsuperscript{35}

\textsuperscript{33} Freitag et al., 2009.
\textsuperscript{34} Browner, 1996.
\textsuperscript{35} Randhir, 2007, 6.
In addition, all related water agencies can create this collaboration framework at the watershed level, which enables people to systematically collect and monitor data, write reports, apply for grants, and make a plan for water allocation and enhancement, while reducing interagency the overlapping in tasks and project funding. Despite economic and human resource constraints, decision-makers have to decide what should be done first to solve water-related problems by rating the priority of each problem within the watershed, and then moving into action steps to improve the current situation in sustainable way.

UNEP defines IWRM as a concept that comes from practitioners’ experience or experiments. In 1992, at the World Summit on Sustainable Development, the meaning of this word in practice was first discussed, and the Global Water Partnership (GWP) defines IWRM as a step of promoting the integrated water, land and related resources management and development, and the maximization of the use of resources in an equitable and sustainable manner concerning ecosystems.

The Thai government has used the IWRM approach as a framework to deal with water problems for a decade. It formed the Chi River Basin Sub-Committee to work with governmental and private agencies that have river responsibilities, and with local people, but it has not succeeded in managing water in the Chi Watershed. The roadmap for IWRM that Thailand created includes the following steps:

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37 Hassing et al., 2009, 3.
38 Wanjararath et al., 2006.
I. Understanding the IWRM concept and developing a unity agreement on IWRM between the water organization, professionals, and stakeholders is the first step that can lead to proficient water resource management. Through workshops and seminars, they created a national water resource management vision.\(^{39}\) The vision in 1999 stated that Thailand, with good water management, a good legal system, and a good organizational structure, will be able to provide enough clean water to water users with equitable and sustainable water resource utilization, a quality standard of living, and with all stakeholders sharing their ideas on water issues.\(^{40}\)

II. The second step is engaging higher-level governmental decision-makers in the IWRM process because with their endorsement, IWRM will be included in water policies and programs. The recommendation from water-related agencies and a stakeholders’ meeting will be proposed to the National Water Resources Committee (NWRC) for approval. After that, it will be sent to the Government Cabinet to consider the possibility and take action to solve water problems.\(^{41}\)

\(^{39}\) Anukularmphai, 2010.
\(^{40}\) Pattanee, 2008.
\(^{41}\) Anukularmphai, 2010.
In the past, since water-related agencies in Thailand did not involve people in the planning process and work collaboratively, they could not manage water well, and were not able to supply enough water for the growing population. There were more than 31 agencies that were responsible for managing water resources, and their duties often overlapped. The Thai government tried to make them work in a coordinated way and created, in 1989, the National Water Resources Committee to gather information about water resources and water projects, and to propose a long-range national water management plan. In 1997, the committee created a

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policy concerning watershed management, implemented the structural rearrangement of concerned agencies, and crafted the Water Resources Act. It set out water policies, approved by the central government in 2000, within an Integrated Water Resources Management (IWRM) framework. One of the policies centered on setting up water management organizations at national and watershed levels because the government at that time set a goal that by 2025, Thailand would supply enough high-quality water to all residents and economic sectors and have a manageable system and law that could improve the people’s quality of life. It would equitable water distribution and includes the involvement of all water-related stakeholders.\textsuperscript{43}

In 2002, the Ministry of Natural Resources and Environment was founded, and, thus, many agencies that had been responsible for water management were transferred and reorganized to work under the same department. The goals of this department are to improve the environment, both in cities and rural areas, and to raise the people’s quality of life.\textsuperscript{44}

The Department of Water Resources, working under Ministry of Natural Resources and Environment, has policies to manage and conserve water resources in an efficient and sustainable way, to support local agencies, and for stakeholders to be engaged with it to create better water plans that benefit the most people. It divided the Chi Watershed into two parts. The upper part, covering the area of five provinces (Chaiyaphum, Khon Kaen, Mahasarakham, Nongbua Lamphu and Udon Thani Provinces), and the lower part, covering three provinces (Kalasin, Roi-Et and Yasothon Provinces), and the Chi River Committee was created to take care of those two parts. The committee comprises representatives of governmental and private agencies, water

\textsuperscript{43} Wanjararath et al., 2006.
\textsuperscript{44} Wanjararath et al., 2006.
management specialists, local people and farmers. From research conducted by Wanjararath et al., people who were part of the committee did not fully understand the role of the committee, and, although they had agreed to use the IWRM approach, most people on the committee did not know in-depth about how that approach would work. Because of that, it did not solve problems efficiently, and it did not provide people with a long-range plan, but only with a short-sighted plan. Moreover, there was no coherence and government agencies exercised power over the other groups of people on the committee and made most decisions on their own.45

It can be assumed, then, that there is no true coordinated effort to manage water at the regional or watershed level in Thailand. However, focusing on the big picture or on the whole watershed is necessary for understanding the underlying causes of problems and the impact of one part of the watershed on the other, and all jurisdictions that lie in same watershed have to work together to achieve better results.

In addition, the proposed plan summited by the committee to the Department of Water Resources in 2005 for a government grant emphasized structural projects rather than focusing on other activities such as data management and conserving the environment. It did not pay attention to important non-structural planning aspects.46

However, managing water resources and planning for water-related activities are equally important. For example, it is important to delineate a buffer around the river to prohibit development in that buffer area so that less land will be affected by excessive water volume, and,  

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45 Wanjararath et al., 2006.  
46 Wanjararath et al., 2006.
in turn, the impact of land activities on water is reduced. Land use regulation and zoning guide
the patterns of development and discourage people from developing in unsuitable areas.47 The
consistency of these regulations across administrative boundaries is needed to reduce the
conflicts among water-user groups and negative effects on water quality. Even though flooding is
a result of heavy rain for a long period of time in the monsoon season, misuse of land can also
worsen the flooding problem. For example, people deplete forests to make room for new
croplands and create irrigation areas causing flooding downstream, as they have changed the
natural systems in upstream jurisdictions for retaining water.

Thus, watershed management needs a comprehensive plan to take the influences of humans and
nature into consideration when managing water resources in the watershed. The plan should not
only state problems, but also provide goals and how to achieve those goals through a bottom-up
approach.

EPA defines a watershed as an area that water passes by either underground or on the surface
and runs to the same water body.48 DeBarry writes, “All land which is part of the watershed
boundary is defined by the higher elevations or ridges that defined which direction the rainwater
will flow.”49 People identify the boundaries of water resources by delineating the watersheds and
assigning them hydrologic units from the largest to the smallest. To delineate the boundaries, a
topology map is used to find water bodies, and then to start tracing the drainage direction of the
watercourse from the outlet point to the point with a higher elevation of contour line. After that,

it is necessary to locate the breaking points which are the highest points that divide the runoff into half running towards different water bodies. Next, drawing a line to connect those points results in the watershed boundaries.\textsuperscript{50} Watersheds are hydrologic units that can be categorized by the size of the watersheds from the largest to the smallest that lie within them. Each watershed, representing unique geographic features, is assigned a hydrologic unit code (HUC), according to its hydrologic unit system’s class. In Thailand, watersheds consist of one to four hydrologic digits; two are for the main 25 watersheds, and four are for 254 sub-watersheds.\textsuperscript{51}

\textsuperscript{50} Hermance, n.d., 114-17.
\textsuperscript{51} BRDH, 2009.
<table>
<thead>
<tr>
<th>Main Basins (HUC)</th>
<th>Name of River Basin</th>
<th>Catchment Area (km²)</th>
<th>Average Runoff (10^6 \text{ m}^3)</th>
<th>Storage Capacity (10^6 \text{ m}^3)</th>
<th>Irrigation Area (Rai)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Salawin</td>
<td>17,920</td>
<td>8,571</td>
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<td>4</td>
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<td>6</td>
<td>Ping</td>
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<tr>
<td>7</td>
<td>Wang</td>
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<td>Yom</td>
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<tr>
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<td>Nan</td>
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<td>9,158</td>
<td>9,619</td>
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<td>10</td>
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<td>20,125</td>
<td>22,015</td>
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<td>11</td>
<td>Sakaekrang</td>
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<td>Pasak</td>
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<td>22,300</td>
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<td>Prachinburi</td>
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<td>Pen. East Coast</td>
<td>13,830</td>
<td>11,115</td>
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</tr>
<tr>
<td>19</td>
<td>Phetchaburi</td>
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<td>20</td>
<td>Pen. West Coast</td>
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<td>1,420</td>
<td>537</td>
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<tr>
<td>21</td>
<td>Southeast Coast</td>
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<td>1,780,481</td>
</tr>
<tr>
<td>22</td>
<td>Tapi</td>
<td>12,225</td>
<td>12,513</td>
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<td>Songkhla Lake</td>
<td>8,495</td>
<td>4,896</td>
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<td>24</td>
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<td>3,858</td>
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<td>337,878</td>
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<tr>
<td>25</td>
<td>Southwest Coast</td>
<td>21,172</td>
<td>25,540</td>
<td>20</td>
<td>339,273</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>512,066</strong></td>
<td><strong>244,431</strong></td>
<td><strong>70,769</strong></td>
<td><strong>31,025,989</strong></td>
</tr>
</tbody>
</table>

Table 1: Main Watersheds in Thailand

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Figure 4: Locations of Thailand, the Chi Watersheds and the Fourth Part of Lam Nam Chi

The Chi Watershed, which has a hydrologic unit code of 4, is the center of this study. However, focusing on the whole Chi Watershed may take a long period of time by a large number of people to analyze, which is beyond the resources available for this thesis. Therefore, Chi River Part 4, which is one of the Sub-watersheds of the Chi River, is selected as the specific study area of this work.
Table 2: Sub-watersheds within the Chi Watershed

<table>
<thead>
<tr>
<th>Hydrologic Unit Code</th>
<th>Sub-watershed</th>
<th>Area (km²)</th>
<th>% Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.02</td>
<td>Chi River –Upper Part</td>
<td>3,393</td>
<td>5.19</td>
</tr>
<tr>
<td>4.03</td>
<td>Lumsapong</td>
<td>725</td>
<td>1.51</td>
</tr>
<tr>
<td>4.04</td>
<td>Lumkrajuan</td>
<td>876</td>
<td>1.82</td>
</tr>
<tr>
<td>4.05</td>
<td>Lumkunchu</td>
<td>1,734</td>
<td>3.53</td>
</tr>
<tr>
<td>4.06</td>
<td>Chi River Part 2</td>
<td>3,808</td>
<td>7.73</td>
</tr>
<tr>
<td>4.07</td>
<td>Huaysammo</td>
<td>774</td>
<td>1.56</td>
</tr>
<tr>
<td>4.08</td>
<td>Chi River Part 3</td>
<td>3,257</td>
<td>6.67</td>
</tr>
<tr>
<td>4.09</td>
<td>Numpong–Upper Part</td>
<td>4,186</td>
<td>8.41</td>
</tr>
<tr>
<td>4.1</td>
<td>Huaypoy</td>
<td>951</td>
<td>1.88</td>
</tr>
<tr>
<td>4.11</td>
<td>Lumpaniang</td>
<td>1,859</td>
<td>3.85</td>
</tr>
<tr>
<td>4.12</td>
<td>Numprom</td>
<td>2,253</td>
<td>4.5</td>
</tr>
<tr>
<td>4.13</td>
<td>Numchen</td>
<td>2,731</td>
<td>5.91</td>
</tr>
<tr>
<td>4.14</td>
<td>Numpong–Lower Part</td>
<td>2,314</td>
<td>4.71</td>
</tr>
<tr>
<td>4.15</td>
<td>Huaysaibaht</td>
<td>664</td>
<td>1.38</td>
</tr>
<tr>
<td>4.16</td>
<td>The fourth part of Lam Nam Chi</td>
<td>5,255</td>
<td>10.37</td>
</tr>
<tr>
<td>4.17</td>
<td>Lumpound –Upper Part</td>
<td>3,216</td>
<td>6.65</td>
</tr>
<tr>
<td>4.18</td>
<td>Lumpanchad</td>
<td>689</td>
<td>1.42</td>
</tr>
<tr>
<td>4.19</td>
<td>Lumpound – Lower Part</td>
<td>3,996</td>
<td>8.84</td>
</tr>
<tr>
<td>4.2</td>
<td>Lumnumyoung</td>
<td>4,050</td>
<td>8.56</td>
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<tr>
<td>4.21</td>
<td>Chi River – Lower Part</td>
<td>2,744</td>
<td>5.53</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>49,476</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

The fourth part of Lam Nam Chi is located within the latitude and longitude of 15 48N and 102 50 E, which has an area of 5,092.51 square kilometers, covering 30 districts in 4 provinces: Roi-Et, Mahasarakham, Kalasin, and Khonkhan. Most of the land is used for rice farming. Other parts are for farm plants, and fruit plants. The western side of the land area is higher than the eastern part, and the Chi River runs through the middle part of the watershed, from west to east.

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The time that is suitable to grow plants is from March to early November. The population density of the whole watershed is 199 people per square kilometer, and that of Mahasarakham is 178 people per square kilometer.\footnote{55 The Office of Soil Survey and Land Use Planning, March 2010.}

In 2002, the demand for water in the fourth part of Lam Nam Chi from the agricultural sector, the industrial sector and from people using it for everyday living was 688.53 million cubic meters per year, and it was projected to grow from that to 780.20 million cubic meters by 2020, with a rate of increase of 91.67 million cubic meters per year.\footnote{56 The Office of Soil Survey and Land Use Planning, March 2010.}

The data related to the fourth part of Lam Nam Chi will be collected and analyzed in the next two chapters, Chapter 3 and Chapter 4.
Chapter 3: Research Methodology

Research Design

The steps, then, of the methodology, which is composed of a desk study of the relevant literature, a site survey, and GIS and satellite data analysis, are as follows:

I. Review the literature documents and data on these subjects, including GIS data: (1) the major underlying causes of flooding, drought and water resource degradation; (2) land use planning, and (3) water management planning in Mahasarakham.

For the major causes of flooding, drought and water resources degradation, the data to be reviewed include those from the water-related agencies’ websites; published research of scholars in Thailand will also be examined. Then, the land use plan and the zoning regulation document from Mahasarakham’s Office of Public Works and Town & Country Planning will be reviewed, and any available water plans and government policies to cope with flooding, drought and water pollution in Mahasarakham will be examined.

For example, examining the existing watershed plans that were recommended by the National Water Resources Committee and approved by the government, and finding out whether the plans were effective, will be done. If they are not, it is necessary to determine what are the reasons behind that and how can they be developed to meet the national water vision and local people’s needs.
II. Conduct a field visit throughout the province to obtain data through observation and study, including interviewing people who are affected by natural disaster or water pollution, and officers from both the government and public sectors, to assess the potential impacts of land activities on the Chi Watershed and other water resources and vice versa.

III. Assuming there is no integrated land use and water plan, to take existing elements and combine them into a first draft of a document the Mahasarakham authorities can review to improve the coordination of planning and plan implementation. However, if the integrated plan really does exist, the implementation of that plan will be proposed.

Instrumentation and Data Collection

I. The major causes of flooding, drought, and water resource degradation will be determined by answering the following questions:

1. *What have the existing reports suggested as the main causes of the water-related problems?*

2. *What are the causes that those to be interviewed think and why?*

3. *What are the important factors that contribute to impaired quality of water within the study area of the Chi Watershed?*

4. *What are the results of GIS analysis?*

II. The questions to be posed for assessing the effectiveness of the plans proposed by the National Water Resources Committee or of other currently used plans are as follows:
1. Are the plans considering the physical, biological, environmental, economic, and land use aspects of the watershed?

2. Do the plans have weaknesses, and, if they do, what are the impacts of those weaknesses?

3. Do the plans reduce the impact of natural disaster faced by local people?

Existing Plans

After scrutinizing the information about land use and water management in Thailand, there are many plans available, ranging from national to local levels, which are to be reviewed. These are noted below:

I. National Level Plans and Actions

1. The National Economic and Social Development Plan

The Office of the National Economic and Social Development Board is a planning agency, under the Prime Minister’s Office that was first established by Prime Minister Field Marshal Plaek Pibulsongkram in 1950. It has the responsibility of preparing a national development plan every five years, which is used as a framework for developing the economy of Thailand. This section presents two development plans (2007 – 2016), which can be summarized as follows.

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57 National Economic and Social Development Board, n.d, 3,5.
1.1 The Tenth National Economic and Social Development Plan (2007-2011)\textsuperscript{58}

- Focusing on improving agricultural production by (1) supporting farmers to grow high value crops and animals, (2) assigning irrigated areas as a high value productive zone; for example, Thung Kula Rong Hai is supported to be a Jasmine rice growing zone for export; (3) supporting agriculture clusters such as organic agriculture, and Jasmine rice; (4) creating a community-rice genetic promotion and production center to produce good quality seed, and (5) developing water bodies in the upper (Udontani), and lower (Nakhonratchasima, Ubonratchatani) parts of the Northeast Region to full potential.

- Creating an integrated watershed management plan in twenty-five watersheds and increasing the irrigated area by at least 800,000 Rai.

- Growing more trees, building weirs in the upper part of the river and cultivating Velvet grass on the steep slopes.

- Preventing flooding by creating local water retention systems and improving drainage and flood prevention systems in the cities.

- Alleviating water degradation problems by increase the capacity of the combined sewer system of the communities.

- Discouraging monoculture farming and the use of chemicals in the soil.

1.2 The Eleventh National Economic and Social Development Plan (2012-2016)\textsuperscript{59}

- Conserving the arable lands, giving small farmers title deeds and supporting having equal access to land and natural resources.

- Using tax policies to control the use of the land and to reduce pollution.

\textsuperscript{58} National Economic and Social Development Board, 2006.

\textsuperscript{59} National Economic and Social Development Board, 2011.
• Supporting farmers to adopt good agricultural practices that are concerned with the environment and conservation of biodiversity, and to follow the principles of “The King of Thailand's philosophy of sufficiency economy.”

• Promoting tree planting in housing and public space.

• Restoring natural resources, forests, and conservation areas.

• Developing an organized database and using it for planning purposes, developing the management of land ownership and water resources and focusing on integrated water resource management.

• Improving the quality of water resources and making surplus water supply which can be achieved by applying a water infrastructure’s master plan to manage the use of water.

• Preparing risk area maps.

• Preparing disaster planning responses by the private sector, institutions, and local authorities.

• Improving waste water treatment.

Both the Tenth and Eleventh plans emphasis on agriculture and water management but they have some differences in detials.

2. Government Policy

The Constitution of the Kingdom of Thailand 2007 states that the Council of Ministers has to deliver a policy statement to the National Assembly within fifteen days after being
appointed to the position. The statement is a guideline for an administration’s plan, and the Council has to follow it to govern the country.60

On December 30, 2008, Prime Minister Abhisit Vejjajeva gave the following policy statement.61

2.1 Agricultural Policy

• To improve the logistics in agriculture and crop production in order to increase the surplus of the products.

• To support farmers and to improve the ways of raising animals with local participation and the use of alternative energy, to set up a national organization to improve domestic fishing and to conserve animal resources and related industry.

• To rush to find water resources to provide enough water and increase water use efficiency by increasing the number of ponds in the rice fields and dredge canals to reduce flooding in rainy season and drought during dry season.

• To increase the irrigation areas and water system distribution to their full potential.

• To preserve areas that are suitable for agriculture with irrigation infrastructure for long-term agricultural production. To restore soil and to find and arrange land for poor farmers by land banking and giving title deeds to them and to communities that stay on government land which is not in the reserved forests.

2.2 Land Natural Resources and Environment Policy

• To preserve forests and wild animals, create land use zones, support economically forests in suitable areas and to grow vetiver grass to reduce soil erosion. To

60 Petchmani, 2010.
reduce the use of chemicals and restore soil in areas with problems and to set up and improve the overall system in order to manage water, both surface and underground, in response to the increased needs of the economic sector and local consumption.

- To create a prevention/warning system and mitigate the damage effected by natural disaster.

- To control and reduce waste and to increase recycling. To prevent pollution caused by upstream sources at the local government level in order to increase its capacity of waste and water pollution treatment by having a center to handle all the wastes in every province and to enforce the law to prohibit people from polluting water. To promptly solve problems in polluted areas and give an incentive in taxes and rights for people who participate in the global warming and pollution reduction project.

- To encourage people to preserve natural resources and support local organizations and the community with the people’s participation to help in managing and evaluating the effects of the environmental policy.

On August 23, 2011, Yingluck Shinawatra, the current Prime Minister, delivered a policy statement. The policy statements of Mr. Vejjajeva and Ms. Shinawatra have some overlapping elements in that they both want to preserve and protect forests and wildlife resources, to use tax measures to control the distribution of land, and, importantly, to improve water management.\(^62\)

\(^62\) “Policy Statement of the Council of Ministers Delivered by Prime Minister Yingluck Shinawatra to the National Assembly,” 2011.
One of the urgent policies that the Ms. Shinawatra’s Council would carry out in the first year is national-level integrated water management promoting an irrigation land expansion policy. The Council would “encourage on-farm water sources supplemented by efficient water diversion and irrigation networks based on commercial and consumption requirements in the locality.”

3. The National Water Resources and Flood Policy Committee

Thailand has many water-related organizations, but they have been working individually and without any cohesion, which in turn produced fruitless results. Thus, in 2011, the Prime Minister, Yingluck Shinawatra, appointed the National Water Resources and Flood Policy Committee as the sole organization to solve overall water problems in Thailand. The committee has full power to order all involved governmental organizations to take action right away on water-related issues. It could make quick response decisions to prevent damage from floods or droughts, to solve problems that arise and to allocate budgets as needed. According to its website, it has been involved in watershed planning and management activities, and it has divided the watersheds into three zones: upstream, midstream and downstream. The strategies for flood prevention are to reduce the speed of water flows from the upstream watersheds, to use floodgates to control the volume of water in all three zones and to push excess water downstream out to sea.

63 “Policy Statement of the Council of Ministers Delivered by Prime Minister Yingluck Shinawatra to the National Assembly,” 2011.
64 The Office of National Water and Flood Management Policy, n.d.
The committee also has suggested that the government should create a water resource management plan in general for all the watersheds, which could partly handle future floods and droughts, and the government has assigned the Office of the National Economic and Social Development Board to do so. The plan provides the following eight strategic plans.65

- Forest and ecology systems restoration and preservation plan
- Plan for dam management and annual water management
- Improvement and restoration of the already water-related construction plan
- Improvement of the data and prediction system plan
- A specific plan to reduce the effects of water disasters in major areas of economic activity
- Designation of land as floodways and creating a small reservoir plan
- Improvement of the organizational structure plan
- Encouragement of a public participation plan

According to the Office of National Water and Flood Management Policy website, it can be concluded that most projects under these strategic plans mainly focus on the Chao Phraya River Watershed as the National Water Resources and Flood Policy Committee put it as the first priority watershed to prevent and protect the economically important areas of Bangkok. However, the committee has emerged as the group finding a way to help the Northeast Region of Thailand deal with the most current drought (October 2012)

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by suggesting closing of the dam gates and using underground water. This measure was a temporary one, which is not sustainable, because it cannot be used as the long-term plan to prevent the Northeast Region from unbalanced water resource problems.

Due to inaccurate prediction of the storm’s direction, the Northeast Region experienced the drought. Thailand predicted that Tropical Storm “Gaemi,” which was approaching Vietnam, would likely hit the Northeast Region of Thailand with a lot of heavy rain. Thus, it prepared for the excess water to come, while draining out to a lower level the water in the reservoirs. However, it turned out that an unexpected high pressure wind from China caused Gaemi to be deviated from its expected original route. Thus, the region encountered drought instead of flood and has not had enough water for agricultural purposes.

II. Regional Level Plan and Action: Northeastern Regional Plan

The key findings from Northeastern Regional Plan can be listed as follows:

1. The Cause of Droughts and Floods in Northeastern Region

Floods occur when large amounts of rain fall over a short period of time, while droughts occur when there is no rain for a long period of time in the monsoon season. The most affected areas from droughts are the areas on the western and middle part of the region.

2. The Factors Affecting the Use of Land

2.1 The market prices of crops play an important role in influencing land use

In 2005, rice and cassava production increased from the previous year as a result of ample rainfall, but production of sugar cane and corn decreased. Some farmers decided to grow cassava, which had a higher market price and required less water instead. Others decided to grow rubber plants, which is a valuable plant economically.

2.2 Forestland has been invaded by farmers and developers

In 2002, forestlands had decreased to 20.08% of the total area of the region because they were converted to farmlands and residential areas. Farmers want more water for irrigation, and the cities need more water to supply a growing population. The misuse of land and increasing demand for water are the major causes of current and future issues that need to be solved partly through enforcement of land use regulations and water resource development.

2.3 The Government can influence the pattern of land use

The Government believes that there is a tendency that the gasoline price will increase. Thus, it wants to reduce the nation's dependence on imported crude oil and diesel by advocating that farmers grow biofuel plants such as cassava and sugar cane. In addition, there are now a lot of ethanol factories in Nakhon Ratchasima, Khon Kaen, and Nong Bua Lam Phu Provinces.

Policy planning from the Northeastern Regional Plan can be listed as follows:

1. Preservation and Development of Natural Resources and Environment Policy Plan

1.1 Sustainable Land Use Planning
The goal of the policy is to create a land use plan at the provincial and district level and use it as guidance for growing crops in areas with suitable soil and for encouraging crop rotation practices and cover crop growing.

1.2 Pollution Management Policy

To manage pollution, controlling land use activities in polluted areas and restoring the environment is of importance.

2. Upstream Wetland and Swamps Policy Plan

2.1 Water Right and Environmental Water Requirements

There should be the creation of a water rights act to control the distribution of water and establish the right to remove and beneficially use water.

3. Upstream and Swamp Restoration and Increased Forest Lands Policy Plan

The use of upstream wetlands and swamps is prohibited.

4. Natural Hazard Prevention Plan

4.1 Flood Prevention Policy

- Flood zones, which are the areas that are prone to flood, will be identified by DPT (Department of Public Works and Town & Country Planning) according to flood risk levels. An example of an area with a high annual chance of flooding is Tung Kula Rong Hai on the Chi River Watershed in Mahasakham, Kalasin, and Yasothon Provinces. Most areas, especially in Khon Kaen and Roi-et Provinces
(on the Chi River Watershed), and Sesaket and Ubonratchatani Provinces (on the Mun River Watershed) are flooded due to excessive water in the river.

- An escape and refuge plan, flood hazard warning systems and a choropleth map on irrigation will be created. There are goals to alleviate possible flooding effects, to slow down water flow over the soil and approaching flood plains by building dams, which will decrease water velocity from the upper stream and restore community forests.

4.2 Drought Prevention Policy

Drought Zones are classified by DPT according to the frequency of droughts within the areas. Surface and underground water sources of communities should be developed and preserved, and the number of trees should be increased. In addition, seeding clouds with chemicals to make rain over agricultural land and reservoirs and creating drought hazard warning systems are other options to help farmers.

5. Water Resources Management Policy Plan

5.1 Integrated Water Resources Management Policy in the River Midstream and Downstream

Developing small water resources and creating ponds in fields are necessary for agriculture. The quality of water should be improved by facilitating cooperation between the government, the private sector and communities and by allowing them to monitor water management and improve regulations.
5.2 Policy for Reservoir Development and Efficiency in the Distribution and Use of Water Rights

- Elevating efficiency of water resources;
- Creating irrigation structures, weirs and ponds to retain surface water;
- Using water pipe systems, which will reduce leakage or loss of water by evaporation, and
- Establishing water resource management organizations at the national and watershed level.

5.3 Water Pollution Control Enforcement Policy

The aim of the policy is to reduce water pollutant emission by putting a price on wastewater treatment and establishing the polluter pays principle. The policy also mandates land use activities in riparian zones which have the potential to affect water quality.

6. Ground Water Policy Plan

Due to a lack of surface water, people use wells to bring underground water to the surface.

A study should be carried out to assess the impact of underground water on water quality.

Not only a policy plan, but also a strategic development plan is included in the Northeastern Regional Plan. The strategic plan is a long-range plan providing strategies on how the Northeastern Region will achieve its vision and implement its policy plan. There are 3 phases to the strategic planning process, which includ 5-year (2012), 10-year (2017), and 15-year (2022) plans.
### 1# Industrial Development on Potential Land

<table>
<thead>
<tr>
<th>The 5-year plan</th>
<th>The 10-year plan</th>
<th>The 15-year plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>- create industrial estate/park</td>
<td>- expand the already existing industrial estate/park and start construction new industrial estate</td>
<td>- be the center of industry in Indochinese Peninsula and expand land for industrial estate/park - plan for land use - prepare specific places for landfill of garbage and waste</td>
</tr>
</tbody>
</table>

### 2# Preserve and Restore Natural Resources and the Environment

<table>
<thead>
<tr>
<th>The 5-year plan</th>
<th>The 10-year plan</th>
<th>The 15-year plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>- explore land, especially conservation areas and water bodies - increase forest land to 20-25% of total current area of forests</td>
<td>- create buffer area for forests near upstream river and forests in conservation zones - increase forest land to 25-30% of total current area of forests</td>
<td>- rehabilitate and restore degraded forests - increase forest land to 30-35% of total current area of forests</td>
</tr>
</tbody>
</table>

### 3# Prevent and Mitigate Natural Hazards

<table>
<thead>
<tr>
<th>The 5-year plan</th>
<th>The 10-year plan</th>
<th>The 15-year plan</th>
</tr>
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<tbody>
<tr>
<td>- create GIS database on flood and drought zone in regional and provincial scale - locate suitable areas for hazard industry</td>
<td>- create GIS database on flood and drought zone in district scale - build small dams in the upstream areas of the Khong-Chi-Mun River - move hazard industrial factories to the specific sites</td>
<td>- create irrigation plan in local scale - distribute water among the Khong-Chi-Mun River - make rain and use underground water in appropriate manner - continue with the relocation of factories plan</td>
</tr>
</tbody>
</table>

### 4# Develop Water Resources for Consumption, Agriculture and Industrial Purposes

<table>
<thead>
<tr>
<th>The 5-year plan</th>
<th>The 10-year plan</th>
<th>The 15-year plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>- restore forests in the Khong-Chi-Mun Watershed - increase the number of ground water wells in high risk of drought areas - transfer water between rivers within the same or different watersheds - grow vetiver grass in upstream area to reduce soil erosion problem and to absorb surface water, and build water storages - build weir to store more water - develop drainage system to cover urban, and other areas</td>
<td>- restore forests in the Khong-Chi-Mun Watershed - grow vetiver grass - explore the depth of water resources and determine whether to dredge the resources to increase the depth - carry out a study on water consumption in the Khong-Chi-Mun Watershed - restore drainage system</td>
<td>- restore forests in the Khong-Chi-Mun Watershed - explore the depth of water resources - carry out the extent study on water consumption in the Khong-Chi-Mun Watershed - restore drainage system</td>
</tr>
</tbody>
</table>

Table 3: The Strategic Plan
III. Provincial Group Plan and Action

1. Development Plan of Middle Part of Northeast Region (Khonkaen, Kalasin, Mahasarakham, and Roi-Et)\textsuperscript{69}

1.1 Increase water management efficiency in order to mitigate flooding problems and try to yield full potential from irrigation. Also, produce high value products and value added to Jasmine rice by upgrading safety standards.

1.2 Prepare alternative energy (ethanol) for growing industries by managing a contract farming system that give equal rights to farmers and factory owners and have a zone for growing cassava and sugar cane.

IV. Provincial Level Plan and Action

1. Draft of Principles for a City Plan of Mahasarakham\textsuperscript{70}

Mahasarakham does not have a city plan, but it has a draft of principles for a city plan of Mahasarakham written in 2005, which has never been used.

The draft states that the problems Mahasarakham has been facing are as follows:

- Due to Mahasarakham undulating topography, it is difficult to build irrigation systems. When forests are destroyed, the soil also becomes depleted. Rain falling on the depleting forestland flows quickly and carries salt to the lower areas and also floods those areas.

\textsuperscript{69} The Office of Mahasarakham Province, 2009.
\textsuperscript{70} Department of Public Works and Town & Country Planning of Mahasarakham, 2005.
• Mahasarakham has medium average rainfall compared to other provinces, but it is inconsistent. Some years, there has been heavy rain, but other years, much less. Brooks, swamps, and canals lack depth and cannot hold water at maximum capacity. Thus, if there is no rain for a long period of time, the province will encounter drought. Usually, to mitigate the problem, the Government builds reservoirs. The Irrigation Department has a role in developing water resources, but it can serve only 9.18 percent of the total agricultural area, and the reason that it cannot expand its service area is the lack of water resources.

In the draft, there were two major water-related projects and three main frameworks as follows:

1.1 The Projects

• Tung Kula Rong Hai (a large plateau) development project in Phayakkhaphum Phisai District, which is an important area for growing rice.

• Kong-Chi-Mun Water Resources Development Project.

1.2 The Frameworks

• Developing a plan to manage the garbage and sewer systems.

• Creating a two kilometer buffer around the Chi River as a zone for organic farming and to support cage farming of Nile tilapia.

• Conserving green spaces.

2. Development Plan for Mahasarakham Province (2012-2013)\textsuperscript{71}

\textsuperscript{71} The Office of Mahasarakham Province 2009.
2.1 Current Situation and Action Plan

• Mahasarakham has 2,714,271 Rai for agriculture. 83 percent of its total area is for rice fields (2,012,620 Rai); the rest is for growing economic plants such as sugar cane, and cassava. The strategy here is that these plants need to be developed and supported by modifying the soil, developing water resources and providing seed in order to increase income for farmers. In the future, the food and energy crisis will be more severe due to world environmental changes, and this will decrease production. Thus, it is important for the province to prepare for this future situation and also support raising animals and developing fisheries because they are sources of food. The forests need to be protected by encouraging people to plant trees and use water containers to store water for use in the dry season.

• Mahasarakham is usually affected by floods, especially the area near the Chi River in Kosumpisai, Kantarawichai, and Mueang Mahasarakham Districts, the flat area at Huay Kakang in Mueang Mahasarakham Municipality and the area in the protected flood zone “Ban Toom-Ban Till Irrigation Project”. When the level of water in the Chi River is high, it is because of the extra water that comes from Chaiyaphum Province and from Ubonrat Dam, Khon Khean Province, which flows to Kosumpisai. This leads to excess water which floods areas in Kosum Pisai, Kantrarawichai, and Mueang Mahasarakham Districts. Mahasarakham can solve the problem by (1) draining water from Huey Kakang that floods the municipality and surrounding area through floodways; (2) improving KUDIO Reservoir, a small irrigation project, which can help store more water, and (3)
improving the flood prevention project “Ban Toom-Ban Till” to drain water to the Chi River faster.

- With low annual rainfall for the past few years, Mahasarakham has encountered droughts and does not have enough water to use for agriculture. The province can solve the problem by building weirs, flowing artesian wells, dredging the canals and shipping water by truck from nearby regions to contribute to local people. Farmers should also be encouraged to create a pond for retaining water to use in the dry season and to grow plants that require less water.

2.2 Plan Suggestions

- Promote research on the development of agricultural food production, agriculture and renewable energy.
- Promote safety standards of agricultural production.
- Strengthen farmer cooperative and agricultural professional groups.
- Promote investment in agriculture and agro-processing.
- Improve water management systems.

V. Local Level Plan and Action

1. Mueang Mahasarakham District

1.1 Background

72 “Design and Development to Link Somtawin Canal to Kakang Watershed Project in Mueang Mahasarakham Municipality,” n.d.
1. Mueang Mahasarakham District is located on the left side of the Chi River, with a land area of 24.14 square kilometers. It has two important water bodies: (1) Kakang Creek, which is the source of water for agriculture (in the north of the area) and (2) Khong Somtawin Canal (flowing from the west to the east of the area).

1.2 Problems Found in the Water Bodies

- Garbage
- River bank erosion
- Shallow canal
- Water plants that slow down water flow

1.3 The Causes of Flooding in the District

- Monsoon season
- Forest and flood — coming from the west
- Bad storm water system

1.4 Flood Control and Problems

- Flood gates control excess water from the Kangleungjarn Weir by leading it through a man-made canal going down to the Chi River at Ban Tha Song Korn Village. However, in some years, water can flow over that weir, and the water level of the Chi River becomes high. The excessive water cannot be pushed into the river at a rate that is fast enough. Thus, the Irrigation Department has to release the extra water to the flat plain to the north of Mahasarakham municipality.

1.5 Projects
The most important proposed projects for Mueang Mahasarakham District are to build an elevated highway and to build higher roads with drainpipes to reduce drainage problems and water runoff. The municipality still uses a combined sewer system, which has a capacity of 4,200 cubic meters per day.

VI. An All-Scale Framework of Planning Policy in Mahasarakham Province

All smaller scale plans correspond to a larger one. Authors of these plans have created both structural and non-structural measures in order to lessen the effect of water-related disasters and deal with polluted water. The measures are illustrated below.

<table>
<thead>
<tr>
<th>Measures</th>
<th>Lists and Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural</strong></td>
<td><strong>1. Irrigated areas expansion by building more dams, especially upstream.</strong></td>
</tr>
<tr>
<td></td>
<td>There is an effort to carry out the Upper Chi Development Project in Chaiyaphum Province to mitigate flooding and drought problems. In 2013, the government expropriated land to build two dams called the Prong Khun Petch and Yangnadee Dams. Since these are built on a small scale, Environmental Impact Assessments (EIAs) are not required. However, there should be a report on how they will influence the community near the dams, land and the people living downstream in social, economic and environmental ways so that non-structural plans can be implemented to correspond to the structural ones.</td>
</tr>
<tr>
<td></td>
<td><strong>2. Creation of more retention ponds in rice fields.</strong></td>
</tr>
<tr>
<td></td>
<td><strong>3. Drainage/flood prevention system improvement.</strong></td>
</tr>
<tr>
<td></td>
<td><strong>4. Channels built to deliver excessive floodwater to watercourses.</strong></td>
</tr>
<tr>
<td></td>
<td><strong>5. Channels dredged to increase their capacity.</strong></td>
</tr>
<tr>
<td><strong>Non-structural</strong></td>
<td><strong>1. Land use plan and zoning</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Flood and drought zone shown in maps</strong></td>
</tr>
<tr>
<td></td>
<td>Planners can identify land uses that should not be developed by overlaying these maps on zoning maps, and local government can hold a development project that may be harmed by natural disasters. In addition, the zones can be used as one of the factors to quantify the price for flood insurance. However, in Thailand, insurance is not used as a mechanism to finance disaster recovery, perhaps because no one wants to pay for it, but flood relief funds are distributed by the national government to help people affected by floods. The local government may provide an incentive to promote insurance systems so that the national government can shift their burden of the relief funds to insurance companies.</td>
</tr>
<tr>
<td></td>
<td><strong>Contaminated land regulations</strong></td>
</tr>
</tbody>
</table>
Having special regulations for contaminated land are necessary for land revitalization.

- **High productive zone**
  Arable land should be conserved for agricultural activities, and the local government should discourage chemical use in soils and support crop rotation practices in this zone.

- **Agriculture policy support to the following:**
  - Biofuel and high value crop planting
    Growing what markets need helps farmers earn more income, but the local government should control the amount of land use used to grow those crops.
  - Plantation forestry and forest conservation
    Forest is an element providing clean water and controlling flooding, but a study of tree types that are suitable for the land should be done.

- **Industrial parks**
  Factories in industrial parks share infrastructure such as roads, which may reduce impervious coverage than if separately located, and it is easier to control on-site wastewater treatment.

**2. Wastewater management**
A water tax can be imposed on wastewater treatment by central treatment plants operated by a governmental agency. This will cause people to reduce discharges of organic matter into streams. While local people may go against the idea and continue directly discharging, at least, if the national government enacted a law that enforces wastewater released by the industrial sector to be treated by central treatment plants, the local government can monitor and control the quality of treated water before discharging it.

Using an incentive received from a project to increase public participation in water-related programs may not be considered a good practice. Conceivably, next time, people will not participate in the program if they do not receive any incentives. However, it may make people be aware of the program.

**3. Water rights**
People use water for consumption, agriculture and industry, and, in the dry season, they may have to compete against one another to have the right to access water resources, while only people who operate a factory have to ask for permission from the local government to use public watercourses. The national government should put priorities on various activities and allocate water rights according to the priorities.

**4. Cloud seeding**
Even though there are reservoirs to retain water, sometimes the water supply is not adequate, and it there is not the amount of rain in the region that people expect. Cloud seeding could be performed in such circumstances.

**5. Prediction and warning system improvement**

**6. Changes in organizational structure**

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**Table 4: Summary of Water-Related Plan**
In order to suggest the implementation of an integrated watershed plan, a review of existing plans and actions and existing data is needed. However, comprehensive plans are not reviewed here, because that relate to analysis part of this thesis, which appears in the following chapter.
Humans guide land use patterns and regional characteristics, and they need a plan to direct any unified development of the physical environment that improves the present conditions of the community. To create or implement the plan, a land use evaluation needs to be carried out. The evaluation will identify land use regulations in comprehensive plans and development trends that influence the ecological environment and hydrological features, examine the interaction of and use and other physical and social aspects and water bodies, and spot issues arising from excessive or inappropriate use of land. This analysis will lead to a greater understanding of the relationship between land use and water and to suggestion that help the city to become more healthy and prosperous.

**Comprehensive Plans**

A comprehensive plan is a document adopted by local government that provides a framework to guide the future of a community and addresses the community's goals, policies and projects for land use distribution. It is used as a tool for determining whether to provide public funding for a key project of the community.

Under the Town Planning Act 1975, the Department of Public Work and Town & Country Planning created comprehensive plans only for the two fastest-growing areas of Mahasarakham Province, which are called (1) the Mueang Mahasarakham Plan and (2) the Tha Khon Yang - Kham Riang Plan. The plans were written to comply with the national, regional and provincial
plans, and used as guidance to assist local governments to make a decision on land use issues on a daily basis.

The goals of the comprehensive plans are to encompass physical development, to improve the built environment and transportation, to lift the people's standard of living and to preserve the area’s cultural/natural heritage and environment. To achieve these purposes, zoning and transportation are used to direct the future growth and development of the planning areas. The following discussion and figures outline and illustrate the comprehensive plan details that relate to water problem reduction.

I. Tha Khon Yang -Kham Riang Plan

![Figure 5: Zoning Map for Tha Khon Yang -Kham Riang Districts](image)

The important points are:

- The zoning ordinance implicitly assigns a hierarchical order to the types of land use. It gives higher priority to the High and Medium Density Residential and Commercial Zones than to Low Density Residential and Rural and Agriculture Zones. It permits fewer types of light factories in the former zones. However, it does not prohibit all types of land use, except manufacturing in other zones.

- The ordinance partially protects Low, Medium and High Density Residential Zones, which can be used for residential buildings, government institutions, utilities and infrastructure, from other uses by permitting no more than 50 percent of development for the Low Density Zone, and 10 percent for Medium and High in each area of those zones.

- The ordinance allows developers to use no more than 60 percent of the spaces of overall parcels for building hotels, condominiums and apartments. It does not take the flooding issue into account. If planned well, employing a practice such as density limitation in the flood fringe area may reduce the risk of flooding.

- Buffers of at least 6 meters along highways, rural roads and public roads are included. The buffers give space and time for runoff to be partially treated by constructed vegetated strips before reaching environmentally sensitive areas.

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II. Mueang Mahasarakham Plan (Revision 2)\textsuperscript{76}

The operation of a slaughterhouse is allowed in the Rural and Agriculture Zone, but a slaughterhouse is not allowed to locate close to a building or within residential, school, and hospital areas. The plan also advises that a slaughterhouse should have its own On-Site Sewage Treatment System, because it may pose negative health risks.

\textbf{Figure 6: Zoning Map in Mueang Mahasarakham Plan}\textsuperscript{77}

\textsuperscript{76} "Mueang Mahasarakham Comprehensive Plan," 2011.

\textsuperscript{77} Data Source: "Mueang Mahasarakham Comprehensive Plan," 2011.
The plan is supportive of a mixed-use development in Medium and High Density Residential and public zoning districts and of more public parking spaces.

The Rural and Agricultural Zone is assigned for the mixture of low density housing with agriculture. This zoning states that there should be prevention and control measures for the pollution caused by factories in the Rural and Agricultural Zone. This zoning assists Mueang Mahasarakham District in preserving agricultural and farm land, in offering green buffers to control the growth direction of the city, and, most importantly, in providing floodways which temporarily store flood waters. To prevent the downtown from flooding, Mueang Mahasarakham Municipality traditionally pushes water toward the floodway area where agricultural fields are located. More specifically, water from Leung Jan Reservoir is released to and combined with water in the Somthawin Canal at the south of the city. From the canal, the water flows into the Chi River.

Surface waters from the Chi River, Bua Swamp and Chaingkham Reservoir are major water supplies for Mueang Mahasarakham District. In the dry season, these waters run dry and people do not have enough water for agriculture. Finding new sources of water,
increasing water-holding capacity of existing water sources and improving water quality are measures recommended in the plan.

- Also included is the launching of a campaign that aims to encourage people to use less water, to promote a wastewater recycling program, to maintain water quality and not to allow people to encroach on public water resources.
- Reducing the traffic congestion in the city by building bypass roads is also suggested.
- The Plan supports the municipality to expand horizontally using the concept of mixed-use development. There are still places for the city to grow, but in the long term, vertical expansion should be considered, as the demand for accommodation from the out of province and international population may increase in the future. Students without private motor vehicles may prefer to live in an apartment close to a school rather than to accommodations further away. Typical mixed-use buildings where the first floor is used for commercial activities and the second floor is used as an accommodation or storage facility can be seen in the CBD.
- The drainage system does not cover the whole district, and combined sewer systems were built to serve only the eastern side of the municipality. Residential wastewater in out of service areas is discharged directly into a public watercourse leading to water pollution.
- Building setback is required to provide a break between buildings and roads for infrastructure.
- Setting up a conservation zone which regulates how people provide open space on every parcel of land is advocated.
- Agriculture is to act as a green belt at the northeast, eastern, western and southern edges of the community.
• The ordinance also does not allow any building taller than 12 meters to be located within 50 meters of the river bank.

Additional regulations of the comprehensive plans of areas within Mahasarakham Province can be found in the Government Gazette,\textsuperscript{78} which regulates density restrictions, building heights, setbacks, green and parking spaces, and streamside zones in commercial zones. However, both the plan and gazette do not mention subdivision ordinance requirements such as the layout of streets, drainage, or water and sewer infrastructure.

The regulations related to hazard and pollution mitigation in the Government Gazette are:

• It requires an at least 6-meter buffer around public water bodies that have a width of 10 meters or greater, and a 12-meter buffer around large water bodies such as marshes or lakes.

• At least one parking space for a car is required for a building with a total floor area of 20 square meters, and developers need to provide parking spaces at a ratio of one car per 40 square meters of floor area for the first 1,000 square meters of a building.

• A temporary waste disposal site has to be located at least 10 meters away from property boundaries of other people or from public streets.

From the regulations above, there are three main issues that need to be addressed.

\textsuperscript{78} Cheunwaree, 2012.
First, assigning only a streamside zone may not be enough. There are more zoning elements that can be utilized to reduce the effect of floods and pollution runoff. Floods usually occur in the area close to the Chi River. Designating the riparian zone is an appropriate way of identifying the areas that are prone to floods or affect water quality. The zone can be subdivided into three zones: streamside, middle, and outer zones. Streamside is the most important one, as it is located where the land meets the water. The outer zone functions as a filtering area, while the middle zone gives a break between the two.\textsuperscript{79} Aside from the riparian zone, flood zoning with floodplain boundaries, density regulations on floodplains, setbacks, nonconforming-use regulations, special-use permits and overlay districts can be included in the gazette. The local government should compile the floodplain boundaries.\textsuperscript{80} Second, parking is a necessary amenity in the commercial area, but the regulation omits runoff issue related paved parking. Finally, even though giving a break between a temporary waste site and neighboring land uses such as residential areas or public roads can relieve the impact of noise, traffic and dust remain as concerns of the local people. In addition, the regulation does not discuss the buffer zone that separates waste management units from water features.

There is a mutual coherence between the comprehensive plan and natural hazard mitigation or storm water pollution prevention elements and, therefore, they need to be implemented. In addition, before implementing the plan, the local government needs to analyze data in the watershed system. Randolph states that drainage areas have been critically important for land and water use decision-making. The tiered approach adopted by the Center for Watershed Protection (CWP) is categorized according to drainage area size, which range from basin to catchment.

\textsuperscript{80} Schwab, 2010, 48-49.
Each category shown below in the table has been influenced by impervious surface at a different level and requires a different type of management.  

<table>
<thead>
<tr>
<th>Watershed Management Unit</th>
<th>Typical Area (sq mi)</th>
<th>Influence of Impervious Cover</th>
<th>Sample Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin</td>
<td>1,000-10,000</td>
<td>Very weak</td>
<td>Basin planning</td>
</tr>
<tr>
<td>Subbasin</td>
<td>100-1,000</td>
<td>Weak</td>
<td>The basin plan is a guide for public Policies and for financial and technical support.</td>
</tr>
<tr>
<td>Watershed</td>
<td>10-100</td>
<td>Moderate</td>
<td>Watershed-based zoning looks at the relationship between a watershed’s current and future conditions and impervious cover. This management helps local governments identify which development in a subwatershed needs to be shifted to other areas in order to sustain the quality of the receiving water.</td>
</tr>
<tr>
<td>Subwatershed</td>
<td>1-10</td>
<td>Strong</td>
<td>Stream classification and management, showing drainage networks that are vital for developing an action plan and strategies. Local government can work on a subwatershed, which is easy to manage, with stakeholders involved in the issues.</td>
</tr>
<tr>
<td>Catchment</td>
<td>0.05-0.50</td>
<td>Very Strong</td>
<td>Practices and site design</td>
</tr>
</tbody>
</table>

Table 6: Tiered Approach

Population Growth Projection

One of the important components for land use planning is population estimation. It provides planners with estimated data for land demand in the future. This can predict the land consumption rate for housing and the numbers of units needed to accommodate a growing

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82 The Stormwater Manager's Resource Center, n.d.
population in the study area. The plan has to support residential areas in the zone that has a sewer system and water in place in the present or during the plan period.

The population growth model used in this thesis is called a geometric population model. It is used to project the population of Mahasarakham Province, Mueang Mahasarakham District and Kantarawichai District in 2020.
<table>
<thead>
<tr>
<th>Index number (T)</th>
<th>Year (n)</th>
<th>Population</th>
<th>Log Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2000</td>
<td>937,860</td>
<td>5.9721</td>
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<tr>
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<td>939,920</td>
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<td>3</td>
<td>2002</td>
<td>942,909</td>
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<tr>
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</tr>
<tr>
<td>21</td>
<td>2020</td>
<td>935,858</td>
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</tr>
</tbody>
</table>

**Table 7 and Figure 7: Population Growth Projection of Mahasarakham Province (Geometric Population Model)**

Data Source: Department of Provincial Administration, Ministry of Interior.
<table>
<thead>
<tr>
<th>Index number (T)</th>
<th>Year (n)</th>
<th>Population</th>
<th>Log Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2000</td>
<td>100,435</td>
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<td>14</td>
<td>2013</td>
<td>98,243</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>2014</td>
<td>98,333</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>2015</td>
<td>98,424</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>2016</td>
<td>98,514</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>2017</td>
<td>98,605</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>2018</td>
<td>98,696</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>2019</td>
<td>98,787</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>2020</td>
<td>98,878</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>est. log values</th>
<th>antilog values</th>
</tr>
</thead>
<tbody>
<tr>
<td>alpha</td>
<td>4.9867</td>
</tr>
<tr>
<td>beta</td>
<td>0.0004</td>
</tr>
</tbody>
</table>

**Table 8 and Figure 8: Population Growth Projection of Mueang Mahasarakham District (Geometric Population Model)**

Data Source: Department of Provincial Administration, Ministry of Interior.
<table>
<thead>
<tr>
<th>Index number (T)</th>
<th>Year (n)</th>
<th>Population</th>
<th>Log Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2000</td>
<td>74,826</td>
<td>4.8741</td>
</tr>
<tr>
<td>2</td>
<td>2001</td>
<td>72,437</td>
<td>4.8600</td>
</tr>
<tr>
<td>3</td>
<td>2002</td>
<td>73,164</td>
<td>4.8643</td>
</tr>
<tr>
<td>4</td>
<td>2003</td>
<td>73,790</td>
<td>4.8680</td>
</tr>
<tr>
<td>5</td>
<td>2004</td>
<td>75,906</td>
<td>4.8803</td>
</tr>
<tr>
<td>6</td>
<td>2005</td>
<td>76,438</td>
<td>4.8833</td>
</tr>
<tr>
<td>7</td>
<td>2006</td>
<td>76,772</td>
<td>4.8852</td>
</tr>
<tr>
<td>8</td>
<td>2007</td>
<td>75,117</td>
<td>4.8757</td>
</tr>
<tr>
<td>9</td>
<td>2008</td>
<td>74,878</td>
<td>4.8744</td>
</tr>
<tr>
<td>10</td>
<td>2009</td>
<td>56,221</td>
<td>4.7499</td>
</tr>
<tr>
<td>11</td>
<td>2010</td>
<td>56,253</td>
<td>4.7501</td>
</tr>
<tr>
<td>12</td>
<td>2011</td>
<td>62,517</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>2012</td>
<td>61,207</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>2013</td>
<td>59,924</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>2014</td>
<td>58,668</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>2015</td>
<td>57,438</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>2016</td>
<td>56,234</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>2017</td>
<td>55,055</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>2018</td>
<td>53,901</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>2019</td>
<td>52,772</td>
<td></td>
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<tr>
<td>21</td>
<td>2020</td>
<td>51,665</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>est. log values</th>
<th>antilog values</th>
</tr>
</thead>
<tbody>
<tr>
<td>alpha</td>
<td></td>
<td>4.9064</td>
<td>80,612</td>
</tr>
<tr>
<td>beta</td>
<td></td>
<td>-0.0092</td>
<td>0.979039017448051</td>
</tr>
</tbody>
</table>

Table 9 and Figure 9: Population Growth Projection of Kantarawichai District (Geometric Population Model)\textsuperscript{86}

\textsuperscript{86} Data Source: Department of Provincial Administration, Ministry of Interior.
According to projections of population growth, Mahasarakham will face a population decline from 940,911 in 2010 to 935,858 in 2020. The diminishing figure corresponds to the decreasing number of Mueang Mahasarakham and Kantarawichai District (the main urban areas of the province)’s population. One reason is that between 2003-2008, the province supported participation in the Family Planning Program. Another reason is that the local people sold land to developers as the demand for apartments increased. Mahasarakham is a well-known education city. It is the home of of Mahasarakham University, Rajabhat Mahasarakham University, Mahasarakham Vocational College, Mahasarakham Technical College, Mahasarakham College of Agriculture and Technology, Praboromarajchanok Institute of Health Workforce Development, Institute of Physical Education Mahasarakham, and Polytechnic College. Students from other provinces in the Northeast Region, from other regions, and exchange students from many counties such as China, and Cambodia come to study at Mahasarakham University. It has increased seats every year to meet demand.

<table>
<thead>
<tr>
<th>Year</th>
<th>Prospective Students</th>
<th>Total Students</th>
<th>Estimated Number of College Graduates</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>10,718</td>
<td>22,120</td>
<td>6,330</td>
</tr>
<tr>
<td>2008</td>
<td>11,443</td>
<td>37,388</td>
<td>10,126</td>
</tr>
<tr>
<td>2009</td>
<td>11,759</td>
<td>38,746</td>
<td>10,611</td>
</tr>
<tr>
<td>2010</td>
<td>12,165</td>
<td>39,624</td>
<td>11,053</td>
</tr>
<tr>
<td>2011</td>
<td>12,263</td>
<td>42,111</td>
<td>11,639</td>
</tr>
</tbody>
</table>

Table 10: Estimated Number of Students at Mahasarakham University

More students mean a greater demand for goods, restaurants and commercial areas. Forests and agricultural lands were converted to apartments and commercial buildings to serve the needs of

out-province and international students. Not only has there been a surge of students, but
merchants have also migrated to Mueang Mahasarakham and Kantarawichai Districts. These
non-residents are not counted as part of Mahasarakham’s population. In 2010, it was estimated
that there were about 60,000 non-residents in the Mueang Mahasarakham Municipality, while
only 40,000 people were residents. This led to the lack of infrastructure funding as the
municipality receives 1,000 baht per a resident per year from the Thai government, and
undercounting means a smaller allocation of funds. In addition, Mueang Mahasarakham
Municipality declared its mission as follows:

- To create and sustain a beautiful and clean city;
- To beautify canals and create good-looking sidewalks;
- To solve inundation and water degradation problems, and
- To build ferro-concrete streets with water pipes.

Thus, Kittisak Kanasawat, the mayor of Mueang Mahasarakham, has persuaded many people to
change their residency.89 In addition, in response to residency issues, Mahasarakham University
established a policy to urge its non-resident undergraduate students to change their household
registration to its old or new campus address. Through May 2012, there were 1,544 students
claiming as a residency Kham Riang Municipality and 445 as a residency Mueang
Mahasarakham Municipality. It also ruled that 100% of the first year students from 2012 would
be required to change their residency.90

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89 “Ask People to Register Citizenship,” n.d.
90 “Minutes Class,” 2012.
The results of the rising population in both Mueang Mahasarakham and Kantarawichai Districts show (1) changes in land use, which has resulted in more runoff; (2) bad effects of increasing amounts of residential; and commercial garbage, and (3) the tendency of having more water and air pollution. Around sixty percent of students at Mahasarakham University’s new campus have motorcycles or scooters, and Mahasarakham has linear development along the streets that promotes the use of motor vehicles, especially motorcycles, as they are a cheap and convenient means of transportation in Thailand. Despite a Mahasarakham Bicycle City Campaign in 2012, the city’s streetscapes do not encourage and support walking and bicycling. In addition, the government’s first car buyer policy (2012) may encourage people in Mahasarakham to buy cars because they get a tax refund.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average</td>
<td>Average</td>
</tr>
<tr>
<td>Number of new private car registrations</td>
<td>2,326</td>
<td>4,950</td>
<td>5,396</td>
</tr>
<tr>
<td>Number of new motorcycle registrations</td>
<td>28,214</td>
<td>36,450</td>
<td>38,841</td>
</tr>
</tbody>
</table>

Table 11: Economic Assumption and Estimation of Mahasarakham Province in 2012 and 2013

Thus, an option for extension development of Mahasarakham is creating more asphalt roads and changing land use and land cover to accommodate the growth of out-province people.

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GIS Analysis

Geographic Information Systems (GIS) is a tool used to show where features are located and how they relate to each other on maps. For watershed planning, GIS is utilized to map land use/cover, soil types, slope, water resources and man-made features, all of which influence the health of a watershed. The maps help planners to make better decisions on watershed management and to come up with plans to maximize the benefits to people and the environment in the long run.

I. Land Cover of the Fourth Part of Lam Nam Chi Watershed

Land cover indicates the visible type of land, which has an impact on watercourse flow. Agriculture may decrease the volume of water in the long term as irrigated plants cause a reduction in runoff volume through evaporation. Urban surfaces are covered by asphalt, which prevents water from infiltrating into the ground, raises total runoff and has an effect on groundwater levels. The flow rate of rainwater is fast and may be confined within urban land. The majority of the watershed is covered by rice fields; the second biggest share goes for field crops. The Thai government has supported farmers to produce more jasmine rice for export and aimed for Mahasarakham to extend rice land by 10,000 Rai in Tung Kula Rong Hai, the biggest plateau of the Northeastern Region, during the 5-year period (2009-2013).\textsuperscript{92} It has intervened in fixing the rice price. Farmers were assured that they would receive a certain amount of money per ton of rice produced, regardless of fluctuating prices in the market. As a result, more lands have been converted to rice fields.

\textsuperscript{92} Saengkaew et al., 2011, 26.
Compared to agricultural land, built-up land covers only small parts of the watershed. While large groups of the built environment (roads, buildings, parking spaces) are located around main highways such as Highway #23 and Highway #208, the small groupings are spread over the area.

Some Thai travelers who come to Mahasarakham for a short time drive cars and stay on its outskirts. Along the streets that lead to the municipality, there are a number of bungalows providing rooms for rent, which serve travelers, weekend students, parents, merchants, and small businessman. On weekends, most accommodations are usually full. Bungalows are a cheap option for those people.  

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93 Data Source: Land Development Department, Ministry of Agriculture and Cooperatives.  
Like built environments, the forest has a small percentage share in the watershed. Forests tend to have a higher rate of evaporation than shorter vegetation like agricultural crops. Thus, the watershed does not have much in the way of natural runoff controllers.

While open water is surrounded by agricultural lands, and communities, there are some parts, not in close proximity to it, that are prone to drought.

II. Soil of the Fourth Part of Lam Nam Chi Watershed

Soil attributes restrict the use of land. The texture, fertility and more have impacts on how well particular plants grow. Previous land use can also affect soil properties. Removing topsoil for agriculture or construction in fertile land can lead to high costs to reestablish vegetation cover. Before developing land, soil properties should be analyzed because the analysis can indicate which areas are suitable for agriculture, and which for residential and commercial development. The criteria for identifying specific sites suitable for development as built-up areas are as follows:

- The areas that are not suitable for growing rice or have low soil fertility
- The land outside of the buffer streamside zone.

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95 Calder, 2005, 6.
Figure 11: Soil of the Fourth Part of Lam Nam Chi Watershed

Soil drainage restricts water needs and indicates cultivation effectiveness. Chemical analysis indicates how acid deposition can affect the growth of crops and what nutrients or other chemicals need to be added to specific soils.

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96 Data Source: Land Development Department, Ministry of Agriculture and Cooperatives.
<table>
<thead>
<tr>
<th>Soil Map Symbol</th>
<th>Soil Drainage</th>
<th>Soil Texture</th>
<th>Soil Depth</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Very poor</td>
<td>Clay</td>
<td>Very deep</td>
<td>Strongly acidic to moderately alkaline (pH 5.5-8.0)</td>
</tr>
<tr>
<td>5, 5hi</td>
<td>Poor</td>
<td>Clay</td>
<td>Very deep</td>
<td>Strongly acidic to moderately alkaline (pH 5.5-8.0)</td>
</tr>
<tr>
<td>6, 7</td>
<td></td>
<td>Silty Clay Loam</td>
<td>Very deep</td>
<td>Strongly acidic to moderately alkaline (pH 5.5-8.0)</td>
</tr>
<tr>
<td>16hi</td>
<td></td>
<td>Sandy Clay Loam</td>
<td>Very deep</td>
<td>Very strongly acidic (pH 4.5-5.0)</td>
</tr>
<tr>
<td>17, 17hi, 17hiB, 19, 19B</td>
<td></td>
<td>Sandy Clay Loam</td>
<td>Very deep</td>
<td>Very strongly acidic (pH 4.5-5.0)</td>
</tr>
<tr>
<td>18, 18hi, 18hiB</td>
<td></td>
<td></td>
<td></td>
<td>Strongly acidic to moderately alkaline (pH 6.0-7.5)</td>
</tr>
<tr>
<td>20, 20x</td>
<td></td>
<td>Sand</td>
<td>Very deep</td>
<td>Strongly to slightly acidic (pH 5.5-6.5)</td>
</tr>
<tr>
<td>22, 22hi, 22hiB</td>
<td></td>
<td>Clay Loam</td>
<td>Moderate to good</td>
<td>Strongly to strongly acidic (pH 4.5-5.5)</td>
</tr>
<tr>
<td>24, 24B</td>
<td></td>
<td></td>
<td></td>
<td>Neutral to strongly alkaline (pH 7.0-8.5)</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>Clay Loam</td>
<td>Very deep</td>
<td>Strongly to moderately acidic (pH 4.5-5.5)</td>
</tr>
<tr>
<td>33</td>
<td>Moderate to good</td>
<td>Silty Clay Loam</td>
<td>Very deep</td>
<td>Very strongly to moderate (pH 7.0-8.5)</td>
</tr>
<tr>
<td>35B</td>
<td></td>
<td>Sandy Clay Loam</td>
<td>Very deep</td>
<td>Very strongly to moderately acidic (pH 4.5-5.5)</td>
</tr>
<tr>
<td>36B</td>
<td></td>
<td></td>
<td></td>
<td>Moderately acidic to neutral (pH 6.0-7.0)</td>
</tr>
<tr>
<td>37B</td>
<td></td>
<td></td>
<td></td>
<td>Very strongly to strongly acidic (pH 4.5-5.5)</td>
</tr>
<tr>
<td>56B</td>
<td></td>
<td></td>
<td>Moderately deep</td>
<td>Very strongly to strongly acidic (pH 4.5-5.5)</td>
</tr>
<tr>
<td>38, 38B</td>
<td></td>
<td>Sandy Loam</td>
<td>Very deep</td>
<td>Strongly acidic to neutral (pH 5.5-7.0)</td>
</tr>
<tr>
<td>40, 40B</td>
<td></td>
<td></td>
<td></td>
<td>Very strongly to strongly acidic (pH 4.5-5.5)</td>
</tr>
<tr>
<td>41B, 44B</td>
<td></td>
<td>Sand</td>
<td>Very deep</td>
<td>Strongly acidic to neutral (pH 5.5-7.0)</td>
</tr>
</tbody>
</table>

**Table 12: Soil Map Explanation**
Table 13 and Figure 12: Total Area and Percentage of Each Type of Soil Group

The Land Development Department has published a soil survey which documents sixty-two types of soils, fifty-nine of which have been identified within the Lam Nam Chi Watershed.

Land suitable for rice production makes up around two-thirds of the watershed. In spite of low fertility, soil groups such as, for example, # 6 (deep clay), # 17(detailed deep sandy clay loam), and # 22 (very deep sandy clay loam) are preferable for growing rice because they are not well-drained and have a low slope. However, land with the group # 17 is vulnerable to drought, as the ground dries...
quickly. A backup water supply is required, and if not rice, but crops are being cultivated, it is necessary to add organic matter and chemicals to the land of soil group # 22.97

Rice not only prospers in flooded fields, but also on dry soil. However, fields growing rice in this way produce lower yields due to highly acidic composition. This upland rice relies mainly on rainwater. Therefore, it favors the areas that have good drainage and a high water retention capacity. These qualities can be found in soil groups # 18, 33, 35, 36, 38, 40 and 60, which is an aggregate of a clay loam.

Figure 13: Land Suitability for Rice Growing in the Fourth Part of Lam Nam Chi Watershed

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97 Knowledge Management Corner of Nakhon Ratchasima Rice Research Center, 2010.
98 Data Source: Land Development Department, Ministry of Agriculture and Cooperatives.
Field crops thrive well in soil group #41 (sand with medium density), which covers 13.92% of the watershed, but it is recommended that farmers should conserve the soil by growing alfalfa, and add a mixture of natural and chemical fertilizer. Land with soil group #24 (deep sandy clay loam), which covers 14.78% of the watershed, is not suitable to cultivate either rice or field crops, as it has sandy and strongly acidic soil and has low fertility. Farmers should add organic matter and chemicals to help hold soil particles together, which allows for better drainage.

A soil group can dictate slope, which helps identify a tendency to erode. For example, aggregates of silty or sandy soil or land with a steep slope have a high chance of being washed away. The Riverina Environmental Education Centre, Australia classifies land capability on the basis of slope as shown in the table below:

<table>
<thead>
<tr>
<th>Class</th>
<th>Land Limitations</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>i.</td>
<td>Slope 0-1° (0-1.75% slope) Prime agricultural land, fertile.</td>
<td>Many uses, no special soil conservation practices or structures.</td>
</tr>
<tr>
<td>ii.</td>
<td>Slope 1-3° (1.75-5.24% slope) Gently sloping, similar to i. but with minor limitations.</td>
<td>Strip cropping, conservation tillage, crop rotation.</td>
</tr>
<tr>
<td>iii.</td>
<td>Slope 3-7° (5.24-12.28% slope) Soil erosion problems can be severe and limit crop yields.</td>
<td>As for ii., but also structural works including graded banks, waterways and diversion banks.</td>
</tr>
<tr>
<td>iv.</td>
<td>Slope 7-14° (12.28 - 24.93% slope) Not suitable for cropping on a regular basis, soil erosion, shallow, rocky soil, occasional cultivation for pasture renewal.</td>
<td>Better grazing land, practices such as pasture improvement, stock control, fertilizer, minimal cultivation to establish pasture.</td>
</tr>
<tr>
<td>v.</td>
<td>Slope 7-14° (12.28 - 24.93% slope) Soil erosion problems severe, shallow, rocky soil.</td>
<td>As for iv., and structural works, including diversion banks, contour ripping.</td>
</tr>
</tbody>
</table>

---

99 Mazza, Cunningham & Harrison, 2010.
100 Fairfax County, Virginia, n.d.
From the table and map, it can be concluded that:

- Around 98% of the Fourth of Lam Nam Chi Watershed can be used for a wide variety of purposes, especially for agriculture.

- 0.2% of the watershed is covered by soil group # 40C with 5.24 - 24.93% slope, which is not pleasant for agriculture, due to soil erosion, shallow, and rocky soil. However, it can be used for grazing.

- More than 0.4 % of the watershed is composed of soil groups # 40C (5-12% slope), 60 (2 - 12% slope), and 62 (>35% slope), which are erosion prone, have major limitations on crop yields and need structural banks. In 2011, to solve the soil erosion problem, the Land Development Department had a goal of adding 10,787.5 rai of velvet grass in Mahasarakham Province. The velvet grass would be established in a swamp or gully, and would be provided to farmers, and to public or private organizations, by the government.\(^{102}\)

In 2012, Kut Vien Village received more than 1 million baht of flood relief funds and built new roads that are elevated 3 meters above the previous street level. To elevate their land and protect themselves against floods, Kut Vien villagers hired a contractor to fill their land along the river, but experienced 3 meters of land subsidence instead. This happened as a result of not compacting

\(^{101}\) Riverina Environmental Education Centre," n.d.
\(^{102}\) Saengkaew , et al., 2011, 21.
the soil. Without permission from the local government, they should not have filled land in a special flood hazard area.\textsuperscript{103}

\section*{III. Topography of the Fourth Part of Lam Nam Chi}

The composition of different elevations creating slopes and the direction in which a slope faces are vital elements in land use planning. Any site that is to be developed should not be located on swales, as it would have a high tendency to flood, and may block or change waterways. The map shows elevations of the Fourth Part of Lam Nam Chi Watershed. In the upper part within Mahasarakham’s boundary, land has low relief, indicating flat or gently rolling country, while the lower part has higher relief, with more water bodies. Thus, from a topographic standpoint, there is no problem for developers or local people to build commercial buildings, houses, apartments, and factories in most areas of the watershed.

\textsuperscript{103} “Mahasarakham people shocked,” 2011
Figure 14: Soil of the Fourth Part of Lam Nam Chi Watershed\(^{104}\)

With weak land use and water regulations, according to the researcher’s site visit for her field work, it was found that (1) houses in rural areas of the watershed are placed in close proximity to the river or water bodies, as it is easier for farmers to take care of their agricultural and fish farms; (2) manufacturers, such as an ice factory, lay next to the Chi River, from which it pumps water to produce ice, and it may release ammonia to the river, and (3) local people fish and swim in the Chi River and other water bodies. The water next to the Sewage Pump Station is severely polluted; even fish and other animals jump out of the water to the small walkway along it to get more oxygen. Nevertheless, a man with a fishnet was in the water during the site visit, while people with scooters drove on the walkway.

\(^{104}\) The map was created by using data from Google Earth and a draft of the Principle City Plan of Mahasarakham.
IV. Stream Order of the Fourth Part of Lam Nam Chi

The order of stream is categorized by the number of tributaries. The higher the stream order, the larger the waterway, as it is composed of smaller waterways. The larger order streams are seen in areas with a lower slope. They have slower flow and a heavier load of debris and runoff. The top three order streams are environmentally sensitive. Thus, they need to be protected from both point and non-point source pollutants. The size of streams can limit the use of land, and different sizes require different management.  

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105 Briney, n.d.
106 Data Source: Land Development Department, Ministry of Agriculture and Cooperatives.
The Strahler method is used to identify the order of streams ranging from 1 to 12, with 1 indicating first order.

Floods

I. The Causes of Flooding in the Fourth Part of Lam Nam Chi

Floods can be caused by nature, by human actions or by both. The flooding in the Northeastern Region of Thailand usually is a result of heavy rain, errors in forecasting cyclones that lead to water mismanagement, new development or a combination of a number of these.

1. Constant Heavy Rain

The numbers of tropical cyclones entering Thailand varies each year, but the country and encounters an average of three tropical cyclones per year. They usually hit the country in October causing heavy rain, which falls over a long period of time.¹⁰⁷

2. Errors in Forecasting

Thailand has managed water according to meteorological predictions. In 2011, they predicted that Thailand would face drought. Thus, water-related officers stored a large amount of water in dams. When drought did not occur, reservoirs overflowed after the rains came causing flooding in the region.¹⁰⁸

3. New development

Flooding can result from development that obstructs the existing waterway. This problem can be found in every province of the Northeastern Region of Thailand.

¹⁰⁸ “Researcher points out that weather mis-forecast is the cause of floods in Thailand,” 2011.
Although, Mahasarakham receives a budget allocation for its general fund by the Thai government and the government also allocates funds for some programs such as economic development and the Baan Mankong (Secure Housing) Projects to develop low income communities, it should consider possible adverse impacts caused by proposed development such as sport courts, before permitting it, as communities have an impact on the watershed, which is affected by the actions and land use of the communities. According to the Mueang Mahasarakham complaint page, the following is an example indicating the above.

Mueang Mahasarakham Municipality allowed a sport court for the Abhisit 2 community to be built and shops to be established on waterways. It reasoned that the community has limitations on the availability of land that is ideal for establishing the court and a flea market, and that these are what people want. This led to a reduction of the width of the local water-distribution canal from 25 feet to 1, and caused flooding in an alley. The municipality solved the problem by (1) making a gutter through private land and (2) installing a drainage pipe. However, it could have been much worse if the development were larger. These possibilities should be considered before such construction plans are approved.

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109 Muang Mahasarakham Municipality, 2011.
II. Flooding Incidents in the Fourth Part of Lam Nam Chi

A serious flood occurred in 2011 when the Chi River spilled over its banks and, consequently, flooded four districts in Mahasarakham Province and five districts in Roi-Et Province. This overflowing water that breached the dike, together with flash flooding in Pupan Mountain, also devastated homes and rice fields in Kalasin Province. From flooding maps, the patterns of floods in each year are similar, usually along the Chi River. Planners need to scrutinize the flood bed areas to determine the relationship between water uses and land use and come up with a mitigation plan to be utilized in years of serious flooding such as 2011.

Figure 16: Floods in 2005-2011

This study will next move to Chapter 5 where it will use what has been gathered and perceived from the argumentation and data analysis parts of this chapter as inputs in creating a proposal for an integrated land use and water plan for Mahasarakham Province.
Chapter 5: Discussion & Conclusion

The proposal suggested here to promote an integrated land use and water plan for Mahasarakham Province is composed of elements at two broad levels: national and local. The national level plan provides structural concepts that can be applied in local level plans. Even though local plans should correspond to the national plans, they could omit some measures if they are not suitable for their local physical and social environments.

National Level

The national government should set up a single water agency by combining all water-related government agencies to deal with flood, drought and water degradation at the watershed level, and to conserve land, open space, water and natural resources. Departments under it should have responsibilities for:

I. Conducting a report on water demand and supply based on land use, population, precipitation or runoff and groundwater recharge data because all the related information is necessary for the determination of a watershed’s current situation, and also to provide input on watershed management.

II. Studying hydrologic changes, which include erosion of stream banks and flood stages of every major river in Thailand, to understand their causes.

III. Evaluating the effectiveness of existing structural and non-structural measures for water resources and implementing the measures that are found most effective.
IV. Using data from (1), (2) and (3) as inputs to create a framework to promote sustainable management of water resources, which integrates it with land use planning, and to provide guidelines in both published and online versions. These guidelines should cover the following topics:

1. **Stormwater Management**

   - Control water volume by adopting the concepts of canals, retention and detention basins and rainwater harvesting that emphasize water reuse or purification.
   - Reduce the impact of development on water quality by regulating low-density zoning in urban areas and integrating green infrastructure into local plans.
   - Low-density zoning: there is a study comparing runoff rates and impervious surfaces for three different scenarios with different densities developed on an acre of land. The result shows that with the same scale, the higher density of house discharges a lower runoff volume per house and that there is less impervious surface.\(^\text{112}\)

2. **Green Infrastructure**

   Green Infrastructure directs the growth pattern of a jurisdiction or beyond and conserves natural resources through the following green concepts that improve water quality before entering surface waterways, and it controls the amount of water from precipitation and runoff:
   - Green building elements such as green roofs and walls and roof gardens.
   - Green storm water infrastructure such as bio-swales, rain gardens, structural planters and permeable paving.

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\(^{112}\) Farr 2007, 106-110.
- Reforestation and restoration in the riparian zone.

There is a link between water quality and forest in a riparian zone. Growing trees on previously forested areas in the zone is necessary to decrease the flow of valuable soil nutrients into watercourses. Planting native species may be one of the top options, as the soil in each location has a different storage capacity of water that only some species can grow on.

3. *Floodplain Management*

To reduce the risk caused by river flooding or excessive rainfall to people and property, flood zones should be determined and only appropriate uses be allowed. The zones can be sub-categorized by flood frequency and be shown on the maps. The maps also depict natural and artificial waterways or structures.

4. *Resilience, Resistance and Avoidance Design of Buildings*

The best way to decrease the effects of flooding is to locate far away from flood zones. However, population growth may put pressure on local governments to allow developers or individuals to use the land on flood plains where the risk of flood exposure is high. Resilient design decreases the impact of floods on structures; however, it lets water to have access to buildings. Resistance, rather, focuses on preventing building entry to flood water, and the avoidance design of housing includes elevated, raised, piling and stilt houses.

V. Providing financial and technical support to local governments to create their own comprehensive water plans and programs that correspond to the national plan.

Sometimes, tax revenue and a jurisdiction fund from the national government are not adequate to cover the operating costs of plans and programs, and they become stagnant or
never meet their goals. Water technicians also may give some advice, share an outside perspective and provide tools to local governments.

VI. Stipulating participation of citizens in planning processes for creating the comprehensive water plans. The plans are developed to serve the community and people. The people have the right to get involved in the plans that may affect them. Planners need to know what local people want their community to be like in the future, and the people can provide invaluable information that helps planners to gain more insight into the community and to make a better plan. Moreover, the planners would then have community members behind them to support the plan. In sum, the plan itself is carried out by many people so that they need to plan together.

VII. Building collaboration among the national water agency, other governmental organizations, local authorities, nonprofit organizations, universities and water related technicians, and forming a team to do research on watershed management, and to propose and carry on a project to enhance water quality and resilience to flood and drought.

Local Level

Mahasarakham Province is an agriculture based city. Thus, there is a high demand for water to be used in agriculture. Artificial reservoirs have been built to retain water. Sometimes, water demand exceeds the supply. The following are measures that Mahasarakham Province can adopt to reduce the impact of water-related problems.
I. The local government has to discourage people from growing their usual crops outside of the irrigation area, but to grow instead arid crops which are economically favorable, and use zoning to regulate the appropriate use of land.

II. Any company or individual should not have the right to cut and fill in riparian zones without prior permission from the local government. If a development affects the quality of water bodies and the level of water during floods, it should not be allowed.113

III. Roads, utility lines and driveways should be built in parallel with the direction of water flow114, but if it is necessary to be built in opposition to or to obstruct the flow, then a thorough study is a must so that ample waterways can still be provided for water to be reconnected, and to replicate the pattern of water flow prior to construction as much as possible.

IV. Buildings should not be located close to water bodies, and they should be built densely and close to each other, so that there will be more areas for recreation and natural vegetation.

V. Polluted storm water should not be discharged directly into watercourses. In urban areas, pipe drainage systems, which are composed of combined and separate components, are used. In a combined system, wastewater is integrated with storm water. The mixed water is transported to and processed at a wastewater treatment plant, before it is released to water bodies. However, during flood events, overflow can degrade watercourses. However, with separate systems, wastewater and storm water are carried via two separate pipes, but storm water may be released into water bodies without being treated.115 Local

government can use green infrastructure to filter the overflow and untreated storm water. Also, the main issues in on-site wastewater disposal and water supply system design include prevention of flood water entering into sewers, and of discharged water from the systems to become integrated with flood waters.

VI. River dredging should not be allowed if a company or individual does not get a dredging permit from local authorities. To get a permit, a report, providing information on the dredged material’s volume and the sites where material is disposed, should be required.

VII. Monitoring and conducting impact assessment of point source pollution and identifying non-point source pollution are required. All new development projects are required to submit flood risk assessment reports, which include measures of how they will deal with runoff after construction, to local authorities so that any projects will not negatively impact receiving water and land located downstream.

VIII. A pond or basin should not be built on saline land, as it may cause widespread soil salination, but, if it is absolutely needed, ground-covering may be an option.

IX. Flood areas can be used for multiple activities that promote the people’s quality of life and enhance the environment. For example, recreational and parking activities encourage people to walk, exercise and ride bicycles, while using the flood land for generating renewable energy from hay, crop wastes and biogas.

X. Fertilizer nutrients, especially nitrogen and phosphorus, which are required to support the growth of plants in agriculture and house lawns, can nonetheless, pollute surface and ground water through runoff. It is advisable to support the use of organic fertilizer, rather than chemical fertilizer, as it provides proper nutrients to the plants and does less harm to the environment. It is also advisable to encourage the practice of crop rotation; that is,
changing the type of plant being grown to another after a certain period of time. This practice helps to improve soil quality. For example, farmers can alternate planting leguminosae with eucalyptus. \(^{116}\)

XI. Local government should encourage farmers to grow perennial or deep-rooted plants in flooded saline land, because they consume more water leading to decreased recharge to the ground and a reduction in the risk of salt being brought to the surface than shallow-rooted ones. \(^{117}\)

XII. Even if biofuel crops such as eucalyptus and sugarcane bring down the price of gasoline, the local government should set a limit on the amount of land used for growing them. *Eucalyptus* is a fast growing and drought resilient tree used to produce paper and biofuel, and it is a popular tree found in barren and saline lands in the Northeastern Region, but eucalyptus plantations can decrease organic matter in soil and should not be planted in forests or in arable and upstream lands. \(^{118}\)

*Sugarcane* is a perennial grass used to produce ethanol, which is mixed with gasoline, and has a higher tolerance to flooding and drought than rice. It is best to grow sugarcane in areas that are highly prone to natural disasters.

XIII. Fish farming is a practice prevalent along the Chi River. Without supporting water from the Ubonrat Reservoir, farmers cannot operate this aquaculture activity because the water is too shallow. However, many farmers still continue with the practice. \(^{119}\) Sites of fish farming should be shown on a land use map of comprehensive plans and correspond to

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\(^{116}\) Foelkel, 2008.

\(^{117}\) Perennial pasture on saline land can change salt and water balances.

\(^{118}\) Suwannakoot, n.d.

\(^{119}\) “Summary report of fish farming situation in mahasarakham province,” 2013.
the existing infrastructure and sewage treatment systems. Fish farming should be located in appropriate areas to minimize the environmental effects.

In conclusion, Mahasarakham Province can adopt these suggestions and adopt them to its own local level plans to guide the future of the community, and the resulting Integrated Land Use and Water Plan can be used as a tool for determining whether or not to conduct programs related to facilities, land use and water resources, which might affect people in the area and limit their private property rights.
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