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SURFACE WATER POLLUTION CONTROL BY APPROPRIATE EFFLUENT TAXATION: THE THACHIN RIVER BASIN STUDY, THAILAND

Mr. Rachasak Klayklung

A Dissertation Submitted in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy Program in Environmental Management
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Thesis Title	SURFACE WATER POLLUTION CONTROL BY APPROPRIATE EFFLUENT TAXATION: THE THACHIN RIVER BASIN STUDY, THAILAND
By	Mr. Rachasak Klayklung
Field of Study	Environmental Management
Thesis Advisor	Assistant Professor Charit Tingsabadh, Ph.D.
Thesis Co-advisor	Associate Professor Nantana Gajaseni, Ph.D.

Accepted by the Graduate School, Chulalongkorn University in Partial Fulfillment of the Requirements for the Doctoral Degree

.... Dean of the Graduate School
(Assistant Professor M.R. Kalaya Tingsabadh, Ph.D.)

THESIS COMMITTEE

.... Chairman
(Associate Professor Sutha Khaodhiar, Ph.D.)

.... Thesis Advisor
(Assistant Professor Charit Tingsabadh, Ph.D.)

.... Thesis Co-advisor
(Associate Professor Nantana Gajaseni, Ph.D.)

.... Member
(Manaskorn Rachakornkij, Ph.D.)

.... Member
(Assistant Professor Khemarath Osathaphan, Ph.D.)

.... Member
(Assistant Professor Sutat Weesakul, Ph.D.)

ราชศักดิ์ คล้ายคลึง : การควบคุมมลภาวะทางน้ำโดยการจัดเก็บอัตราภาษีที่เหมาะสม กรณีศึกษาลุ่มแม่น้ำท่าจีน (SURFACE WATER POLLUTION CONTROL BY APPROPRIATE EFFLUENT TAXATION: THE THA-CHIN RIVER BASIN STUDY, THAILAND) อ. ที่ปรึกษา : ผศ. ดร. จาริต ติงศภัทิย์, อ. ที่ปรึกษาร่วม: รศ. ดร. นันทนา คชเสนี, 229 หน้า.

แม่น้ำท่าจีนถูกจัดอันดับว่ามีการปล่อยมลภาวะลงสู่แม่น้ำมากที่สุดในประเทศไทย ซึ่งแหล่งมลภาวะที่สำคัญที่เป็นตัวกำเนิดมลภาวะหลักประกอบไปด้วย การทำฟาร์มหมู ชุมชน ฟาร์มเพาะเลี้ยงสัตว์น้ำ และโรงงานอุตสาหกรรม ซึ่งผลที่เกิดขึ้นตามมาก็คือแม่น้ำท่าจีนประสบปัญหาอย่างหนักกับคุณภาพน้ำผิวดิน โดยเฉพาะอย่างยิ่งเมื่อควบรวมกับการสะสมมลภาวะที่มาจากแม่น้ำที่อยู่เหนือแม่น้ำท่าจีนขึ้นไป และจะเป็นการเหมาะสมอย่างยิ่งถ้าสามารถนำแบบจำลองระบบการเก็บภาษีมาประยุกต์ใช้และทำให้ปริมาณมลภาวะที่แหล่งกำเนิดน้ำเสียและปริมาณของน้ำเสียที่สะสมในแม่น้ำท่าจีนไม่เกินความสามารถในการรองรับมลภาวะของระบบนิเวศน์ในแม่น้ำได้

จุดมุ่งหมายของงานวิจัยนี้เพื่อค้นหาระบบการเก็บภาษีที่เหมาะสมสำหรับมลภาวะที่เกิดขึ้นและทำการสร้างแบบจำลองทางคณิตศาสตร์สำหรับประกอบการตัดสินใจในการคำนวณหาสภาวะกำไรที่สูงที่สุดและสภาวะนั้นไม่เกินข้อจำกัดทางนิเวศวิทยาและข้อจำกัดทางเศรษฐศาสตร์ และปริมาณมลภาวะที่เกิดขึ้นจะต้องไม่เกินความสามารถในการรองรับมลภาวะสูงสุดรายวันของแม่น้ำท่าจีนด้วย ขั้นตอนหลักในการทำงานมีทั้งหมดสามช่วง โดยช่วงที่หนึ่งจะเป็นการรวบรวมฐานข้อมูลทั้งหมด ซึ่งคุณลักษณะของข้อมูลจะประกอบไปด้วยข้อมูลเชิงสิ่งแวดล้อมและข้อมูลเชิงเศรษฐศาสตร์ ข้อมูลเชิงสิ่งแวดล้อมนั้นจะเป็นการเก็บข้อมูลที่เกิดขึ้นจริงในแม่น้ำท่าจีนซึ่งเกี่ยวกับคุณลักษณะของมลพิษ ศักยภาพการรองรับมลพิษ ความสามารถในการรองรับมลภาวะสูงสุดรายวัน และเป้าหมายของการลดมลภาวะของแม่น้ำท่าจีน และข้อมูลเชิงเศรษฐศาสตร์จะเป็นการเก็บข้อมูลเกี่ยวกับต้นทุนการผลิต ต้นทุนการบำบัดมลพิษ และกำไรจากผลประกอบการของทุกแหล่งมลภาวะหลักในลุ่มแม่น้ำท่าจีน ช่วงที่สองจะเป็นการคำนวณเพื่อหาสมการต้นทุนหน่วยสุดท้ายในการบำบัดมลพิษ (Marginal Abatement Cost) ของแต่ละแหล่งมลภาวะหลัก และอัตราภาษีมลภาวะที่อยู่ภายใต้การควบคุม ช่วงที่สามจะเป็นการสร้างแบบจำลองทางคณิตศาสตร์สำหรับประกอบการตัดสินใจและกระทำการจำลองสถานการณ์เพื่อหารูปแบบการเก็บภาษีที่เหมาะสม จากผลการศึกษาพบว่าต้นทุนในการบำบัดมลพิษของการเก็บภาษีแบบอัตราเดียว (Uniform tax) จะมีต้นทุนน้อยกว่าการเก็บภาษีแบบไม่ใช่อัตราเดียว (Non-uniform tax) ประมาณ 3,480,944,681.53 บาทต่อปี และค่าใช้จ่ายรวมของการเก็บภาษีและต้นทุนในการบำบัดมลพิษของการเก็บภาษีแบบอัตราเดียวต่ำกว่าประมาณ 3,517,515,764.60 บาทต่อปี ซึ่งเป็นผลทำให้กำไรสุทธิของผู้ประกอบการจากการเก็บภาษีแบบอัตราเดียวมีค่าสูงกว่าการเก็บภาษีแบบไม่ใช่อัตราเดียวประมาณ 3,518,058,488.41 บาทต่อปี และการเก็บภาษีทั้งสองรูปแบบนั้นทำให้มลภาวะอยู่ในระดับที่กำหนด แต่อย่างไรก็ตามเมื่อพิจารณาตามหลักเศรษฐศาสตร์การเก็บภาษีแบบอัตราเดียวมีประสิทธิภาพมากกว่าเพราะปริมาณรายจ่ายโดยรวมในการบำบัดมลพิษต่อรายได้ของผู้ประกอบการของการเก็บภาษีแบบอัตราเดียวมีค่าต่ำกว่าการเก็บภาษีแบบไม่ใช่อัตราเดียวประมาณ 0.552% อนึ่งแบบจำลองนี้สามารถนำไปปรับใช้สำหรับการควบคุมมลภาวะในแม่น้ำอื่นได้

สาขาวิชา การจัดการสิ่งแวดล้อม	ลายมือชื่อนิสิต............................
ปีการศึกษา 2549	ลายมือชื่ออาจารย์ที่ปรึกษา............................
	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม............................

4589673720: MAJOR ENVIRONMENTAL MANAGEMENT
KEY WORD: MARGINAL ABATEMENT COST/ NON-UNIFORM TAX/ UNIFORM TAX/ MATHEMATICAL DECISION MAKING MODEL

RACHASAK KLAYKLUNG: SURFACE WATER POLLUTION CONTROL BY APPROPRIATE EFFLUENT TAXATION: THE THACHIN RIVER BASIN STUDY, THAILAND. THESIS ADVISOR: ASST. PROF. CHARIT TINGSABADH, Ph.D., THESIS CO-ADVISOR: ASSOC. PROF. NANTANA GAJASENI, Ph.D., 229 pp.

The Thachin River was ranked as the most polluted river in Thailand. Pig farms, Urban communities, Aqua cultures, and Industries were significant contributors to deteriorating water quality in Thachin River basin. Consequently, it is facing a serious problem of surface water quality especially when dealing with an accumulation of upstream wastewater discharges. It would be more appropriate, if the taxation model would take into account both the amount of pollution emission at the 'end-of-pipe' and the amount of wastewater contaminant in the surface water which should not exceed the environmental loading or overload the carrying capacity of the river ecosystem.

This research purposed to seek the appropriated effluent tax system and constructed the optimization mathematical decision making model in order to make the maximization profit that met the environmental constraint and economic constraint from Thachin River. Moreover the amount of pollution discharges would not excess Total Maximum Daily Loading of Thachin River. The steps in estimating of appropriated effluent taxation were divided into 3 phases, Phase I, The data collection was divided into 2 aspects which were Environmental aspect and Economic aspect. First Environmental aspect was the actual information which concerned on pollution characteristic, carrying capacity, Total Maximum Daily BOD Loading, and Target of emission reduction of Thachin River. Second Economic aspect concerned on the production cost, abatement cost and the revenue of every activity in Thachin sub-basin. Phase II was the calculation of marginal abatement cost (MAC) of each main point source and the emission tax rate under Command and Control (CAC). Phase III was the construction of Mathematical Decision-making model and simulated by using optimization model for arriving the appropriate tax charge. The result showed that abatement cost of Uniform tax was lower than Non-uniform tax approximately of 3,480,944,681.53 Baht/year. Moreover the total expenses of Uniform tax was lower than Non-uniform tax approximately of 3,517,515,764.60 Baht/year which lead to the higher of net profit of Uniform tax approximately of 3,518,058,488.41 Baht. Both of Non-uniform and Uniform tax reduced efficiently the wastewater emission in Thachin River which met the standard requirement however, in term of economic, the Uniform tax was more efficient than Non-uniform tax because the total expense per revenue of entire river was lower than Non-uniform tax approximately of 0.552 %. The processes in this study are practical in applying of water pollution control in other rivers.

Field of study Environmental Management	Student's signature ...RACHASAK KLAYKLUNG...
Academic year 2006	Advisor's signature ....
	Co-advisor's signature ....

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Finally, if this dissertation possesses any few advantages, they will be dedicated to my beloved parents and sisters for their unconditional love, wholehearted understanding, never-ending encouragement, and patient support for this long journey.

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NOMENCLATURES

Alpha	An ability of pollution release in each point source
a,b,c, and d	Coefficient set
BAT	Best Available Technology
Beta	BOD loading when produce at q unit of each main point source
B.E.	Buddhist era
BMPs	Best Management Practices
BOD	Bio-chemical Oxygen Demand
C	Cost of Abatement
CAC	Command And Control
CGWB	The Central Ground Water Board
COD	Chemical Oxygen Demand
CPCB	The Central Pollution Control Board
CSO	The Central Statistical Organization
CWA	Clean Water Act
DENR	Department of Environment Studies and Natural Resources
DIW	Department of Industrial Work
DO	Dissolved Oxygen
E	Pollution Concentration in Effluent stream
e	Natural logarithm
EEFD	European Environmental Framework Directive
EPBs	Environment Protection Bureaus
EPA	Environment Protection Agency
EU	European Union
F	Total amount of wastewater treatment

FRG	Federal Republic of Germany
FWPCA	Federal Water Pollution Control Agency
I	Pollution Concentration in influent stream
MAC	Marginal Abatement Cost
NPDES	National Pollutant Discharge Elimination System
NSW	New South Wales
PCD	Pollution Control Department
POEO	Protection of the Environment Operation Act
Q	Type of each production in each sub-basin
RMB	Chinese currency "Yuan"
SS	Suspended Solids
TMDL	Total Maximum Daily Loading
TOC	Total Organic Chloride

CHAPTER I

INTRODUCTION

1.1 Description of problem

According to a worldwide Environmental Sustainability Index in December 2002, to show the state of the environment and how it is affected by human activities, Thailand ranked 46th out of 56 countries. This was conducted by the World Economic Forum 2000. Many observers in and outside of Thailand believe that this poor environmental performance is due to the government's lack of will in enforcing existing laws and regulation. They maintain that the Natural Resources and Environment Ministry does not have any real power and authority and that the government needs to take a tougher position to regulate and monitor all developments which impact the environment.

Thailand, considered as one of the "East Asian tigers," was praised for its strong economic growth during the expansion years up to the financial crash of 1997, for example it had more than quadrupled the amount of energy consumed per person, from 11 million Btu per person in 1980 to 46.2 million Btu per person in 2001. However, at the same time the country also suffered from increased levels of industrial wastewater, a dramatic rise in domestic sewage and hazardous wastes, and severe degradation of its water and coastal resources. After 1997 there was an increased awareness that Thailand's economic development must take into greater account the environment in order to be sustainable in the longer-term. Furthermore, based on the Environmental Protection Act (1992), Thailand's 1997 constitution requires the government to conduct public hearings and seek the views of local communities before it embarks on development projects that will have an effect on the environment.

In spite of this legislation, increasingly water reservoirs, rivers, canals and swamps have become severely polluted due to wastewater discharged from many activities such as pig farms, urban communities, aquaculture and industries. Especially, industrial activities generate a lot of wastewater resulting from its high water consumption. Often the wastewater being generated is highly contaminated with both organic and inorganic substances. Legal requirements for factories and industrial parks to treat their wastewater in order to meet the industrial effluent standard could be considered as just an 'end-of-pipe' control. Moreover, as the standard only specifies the concentration of contaminants without taking into consideration the contaminant loading, the amount of wastewater being discharged does not correspond with the carrying capacity of the receiving aquatic ecosystem which is attained by the pollution. Each water basin has its own respective temporal and spatial carrying capacity in absorbing pollution, i.e., different carrying capacities. The deterioration in reservoir water quality has resulted from factory permits which are issued for a specific area but do not conform with the land use, the environment and the carrying capacity of that particular aquatic ecosystem.

In theory, government policy should provide measures to alleviate poverty and promote the development of a sustainable environment. There has been some interesting relevant research and development which has emerged which could be applied in order to promote the standard of living and at the same time improve environmental protection. Naturally, such R&D would be highly appreciated as a possible 'win-win' solution to certain environmental problems. Several projects have been launched to control and minimize pollution and to improve industrial technology. For example, the Thachin River Basin partnership is to establish the "Thachin River Business Coalition" and also enhance the partnership between Thailand-Phillipines and the EPA in USA.

From 2000 to 2002, the Thachin River was ranked as the most polluted river in Thailand. Urban communities and effluent from pig farms in Nakhon Chaisri District, Nakhon Pathom Province were significant contributors to deteriorating water quality in the lower part of the basin

In Thailand, there are twenty-five river basins that increasingly have to deal with pollution loadings which exceeds their carrying capacity.

Thachin River, located in the central region is the main river passing through nine provinces and serves approximately eight million people for domestic, agricultural and industrial uses. Currently, it is being overloaded with wastewater from various industrial, agricultural and urban activities. Consequently, it is facing a serious problem of surface water quality especially when dealing with an accumulation of upstream wastewater discharges.

From a technological point of view, there are evidently many ways to minimize and to mitigate wastewater loading before discharging into a natural aquatic ecosystem especially a river.

However, in Thailand, many researchers have proposed non-technological methods by applying a taxation method to control wastewater effluent not only from industries but also from agriculture and domestic use. Based on this method, a Uniform or Non-uniform Tax has been proposed and applied to deal with pollution emission permits. At present, the Pollution Control Act is used as a uniform tax, which is a single tax rate charge, to control pollution emissions nationwide. This method is not an optimization tax. Although the unit charge is concerned with the amount of pollution emission at the 'end-of-pipe', it does not take the water quality of river after the wastewater has been actually discharged into consideration.

It would be more appropriate, if the taxation model would take into account both the amount of pollution emission at the 'end-of-pipe' and the amount of wastewater contaminant in the surface water which should not exceed the environmental loading or overload the carrying capacity of the river ecosystem. To solve these problems based on a non-technological method, the incentive based method together with a taxation system could be effectively introduced to control pollution discharge levels in order to reduce the pollution loading into the river.

1.1.1 Conflict Management.

At present Thailand has only implemented the 'end-of-pipe' wastewater regulation, which specifies that the Biochemical Oxygen Demand (BOD) at the end-of-pipe shall not exceed 20-60 mg/l, in order to control the quality of wastewater being discharged into a public water source or natural water system. However, this still poses various questions about how to conserve the water quality without serious pollution. A hypothetical situation would be, if thousands of wastewater discharges from individual sources comply to the national effluent standard, then would the river basin be able to absorb them all?

Therefore, in order to further clarify the issue of accumulated loadings, the Total Maximum Daily Loading (TMDL) for each sub-basin is needed in order to better understand and recognize the limits of loading. Theoretically, when a TMDL is set for a sub-basin, the Maximum Load for each pollution activity could be traced back to it's source. This means that the intensity of BOD in each sub-basin would not be identical which would depend upon the specific environmental conditions of both each sub-basin as well as the whole river basin.

Regarding the industrial effluent standards of Thailand, which indicates parameters, standard values and recommended methods for observation and analysis as shown in Table A-1.

In the past, there was an attempt to use taxation to control water pollution. However, this was not successful since each sub-basin has its own specific TMDL, the tax used should therefore vary for each sub-basin depending on the carrying capacity.

For the environmental conditions of the Thachin River in this study, the author used water classification standard class 2, 3, and 4 to determine the TMDL of each sub-basin along the river in Table A-4.

Based on the abatement cost which defines the cost for the treatment of effluent discharges and the marginal abatement cost (MAC) defined as the cost which is sufficient for treatment up to the last unit of effluent. The MAC curve in Figure 1-1 shows that the more polluting substances are released into the environment, the less the abatement spending to be paid by the factories.

Theoretically, effective taxation could be used as a measure for controlling the amount of pollution emissions that could be indicated by the tax line (P_1, P2, and P_3).

This shows where polluters would have to pay a variable tax at each P line if they were to produce any unit of pollution. This could induce them to produce less pollution which would be an amount lower than the appropriate level at the tax line intersection. This point would then provide the MAC that the polluter would benefit from in paying lower taxes.

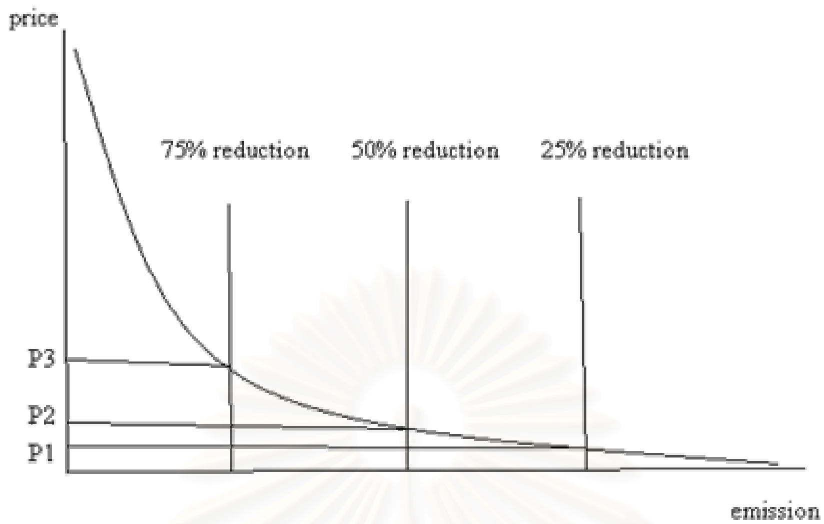

Figure 1-1: Appropriate variation charges at any reduction case

There is a further important reason why non-uniform and uniform taxes should be used. Due to the controlling of ambient water quality in each sub-basin under the water classification standard, we have to consider several factors some of which are the following:-

1) the cost of treatment of each activity; and

2) the pollution carrying capacity ability of each sub-basin.

1.1.2 Current situation of BOD loading in Thachin River

The monitoring of water quality in the Thachin River from the Pollution Control Department (PCD) found that Thachin River has continuously deteriorating BOD values and dissolved oxygen as pollution indictors. The Thachin River catchment has a BOD higher than the surface water standard which should not exceed 4.0 mg/l for downstream, 2.0 mg/l for midstream and 1.5 mg/l for upstream sections. At the same time, the dissolved oxygen is lower than the standard limit 2.0 mg/l for downstream, 4.0 mg/l for midstream and 6.0 mg/l for upstream sections.

Moreover the rapid deterioration rate of Thachin River also has to face severely polluted water in some segments, especially from the end of the dry season through to the rainy season. As can be seen in the pollution water crisis of Thachin River in A.D.2000, which started at the end of April to the beginning of May, coincides with rice harvesting. During that period, the rainfall was more than usual and it covered an area of more than 21,120 ha, resulting in extensive flooding and water pollution in rice fields covered the area of Toon Soangpinong and Suphanburi Province. As a result, in order to resolve the water pollution problem, farmers discharged polluted water into the Thachin River at the middle segment. Consequently, masses of polluted water passed through Banglane District, Nakornchaisri District, and Sampran District of Nakornpathom Province, and continued onto Kratumban and Muang district, Samutsakorn Province. A total distance of 150 kilometers became a dark color and had extremely low Dissolved Oxygen (DO), even reaching 'Zero' at some points, PCD (2005a).

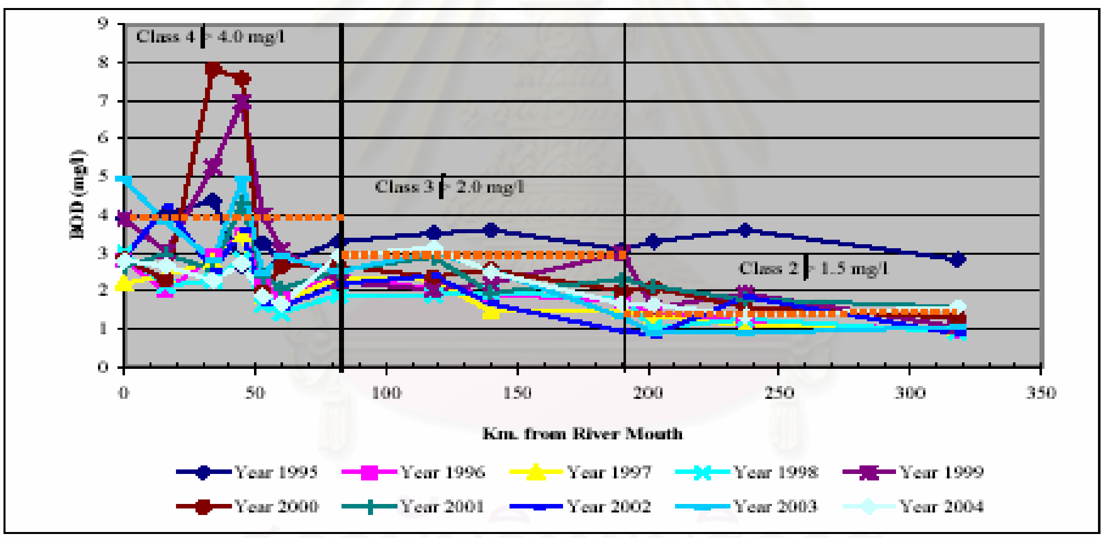

Figure 1-2 BOD value 1995 to 2004

Source: PCD, (2005a)

1.2 Objectives of the study

This research, aims to explore the possible maximum volume of BOD effluent in each sub-basin without causing a deterioration in the river ecosystem. Therefore, the approach taken in this study is to optimize the effluent taxation model in order to control the surface water quality of the Thachin River. There are two specific objectives which are as follows:

1. To find the appropriated effluent tax system to control the pollution loading of the Thachin River.
2. To construct the optimization mathematical decision making model: in order to make the maximization profit to system, that meet the environmental constraint and economic constraint from Thachin River, and the amount of pollution discharges will not exceed Total Maximum Daily Loading of Thachin River.

The results of the database collection (PCD, 2005a) show permitted pollution loading and the targets of emission reduction for the Thachin River. These results will be converted to the abatement costs and tax rates. The wastewater abatement cost, the appropriated variation tax and reduction rate from each sub-basin will be shown in this study. Then these results will be processed by mathematical programming, to give the effects of the taxation system.

The results of study should provide useful information about the optimal taxation level for controlling pollution emissions in each sub-basin of the Thachin River by using the incentive based method. The polluter would pay taxes which are less than the full abatement cost. Furthermore, the environment around Thachin River would be improved because the wastewater discharge level would be controlled by taxation.

This study would also provide valuable information to policy makers to assist them in implementing plans which could be integrated to complete the projected database. This project is a basic database to provide the foundation for an effective quality control policy for the Thachin River. Moreover, this policy could be extended with other methods such as transferable trade permits for future pollution.

Finally, the efforts to support a sustainable environment is at the core of the project, which should lead to an improvement of the Thachin River basin. Thus, the communities in the Thachin river area should also have a the better quality of life. Furthermore, the results of the study could possibly be applied to many of the major rivers in Thailand.

1.3 Hypothesis of the study

The 'Emission Taxation system' could control the pollution discharges of a sub-basin which would then reduce the amount of effluent loading to meet the 'Total Maximum Daily Loading' requirements of Thachin River and also satisfy certain economic constraints.

1.4 Scope of the study

1.4.1 Thachin River

Thachin River is the only major river in the Thachin water basin and is known under several different names depending on the location it passes through, such as the Makhamtao Canal, Supanburi River and the Nakornchaisri River. However, it is commonly known as the Thachin River. It originates from a stream that separates from the right bank of the Chaopraya River at Ban Paakklongmakhamtao, Makhamtao subdistrict, Watsing district, Chainat Province. This then passes through Hanka district, Chainat Province, going to Supanburi Province through the districts of Dermbangnangbuat, Samchuk, Sriprachan, Muang, Bangplama, and Songpinong. It passes through Nakornpathom Province at the districts of Banglane, Nakornchaisri, and Sampran, and flows into the gulf of Thailand at Samutsakorn Province by passing through Banprao, Kratumban, and Muang districts. The total length of the river is 325 kilometers, PCD (2005a).

The Thachin River Basin has a total area of 11,763 square kilometers or 7.35 million rais covering nine provinces, consisting of Bangkok, Ayuthaya, Nontaburi, Chainat, Utaithani, Supanburi, Kanjanaburi, Nakornpathom, and Samutsakorn. A majority of the area, about 99.5 %, is situated in six provinces, excluding Ayuthaya, Nontaburi, and Bangkok. The boundary of Thachin River Basin is shown in Figure 1.3.

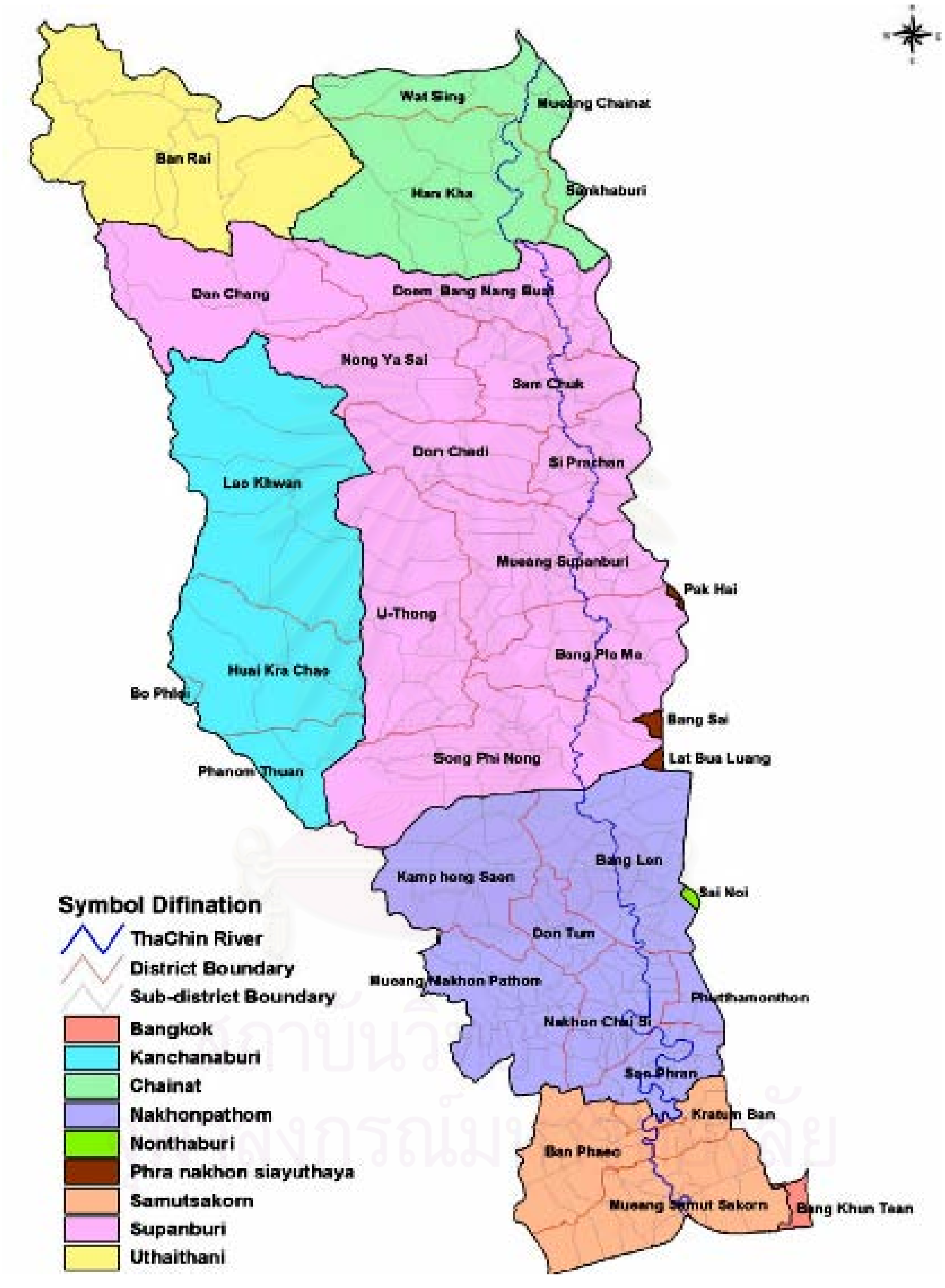

Figure 1-3 The boundary of Thachin River Basin
Source: PCD (2005a)

1.4.2 Using tax system for controlling water pollution in Thachin River sub-basin

In Thailand environmental management is largely carried out at the state level. This is true for natural resources such as forests, land as well as for air, water quality and solid waste pollution. Therefore, the focus of efforts to improve environmental stewardship has to be at the state level. This paper proposes and implements a methodology to evaluate the cost-effectiveness of market-based approaches to environmental management. In particular, using data from the PCD, we quantify potential water pollution control in Thachin River that would result from using a market-based instrument (MBI) such as an emissions tax compared to command and control (CAC) regulations focus on all 4 main polluting sectors.

While there is an existing alternative approach for pollution abatement in Thailand, the policy response to regulate pollution has been through command and control (CAC) strategies. Without going into the compulsions for adopting a Tax Emission approach, there are a number of problems with the current regulatory regime from an economic point of view.

1.4.3 Using BOD represented all types of water polluter

Industrial, agricultural chemicals and organic pollutants from agro-based industries are a significant source of surface and ground water pollution. Understanding the impact of water quality on human health and aquatic life has improved greatly in recent years. Consequently, two broad measures of water quality have come to be widely accepted and used as measures of oxygen levels or oxygen demands in water.

The use of BOD indicators provides an approximate but useful overview of the overall health of a water body and/or the threats confronting it. The procedures required for the measurement of water quality indicators are problem-specific and are generally well understood.

Biochemical Oxygen Demand (BOD) is one of the important parameters used for water quality evaluation including domestic and industrial wastewater, waste treatment monitoring and design. The BOD standard method is measured following the Standard Method for the Examination of Water and Wastewater (Clescerl et al.,1999). BOD waste is one of the most hazardous wastes that contain high amounts of heavy metals substances and toxic substances. These hazardous wastes generate from BOD are a major cause of serious problems threatening public health and the environment.

1.5 Conceptual Framework

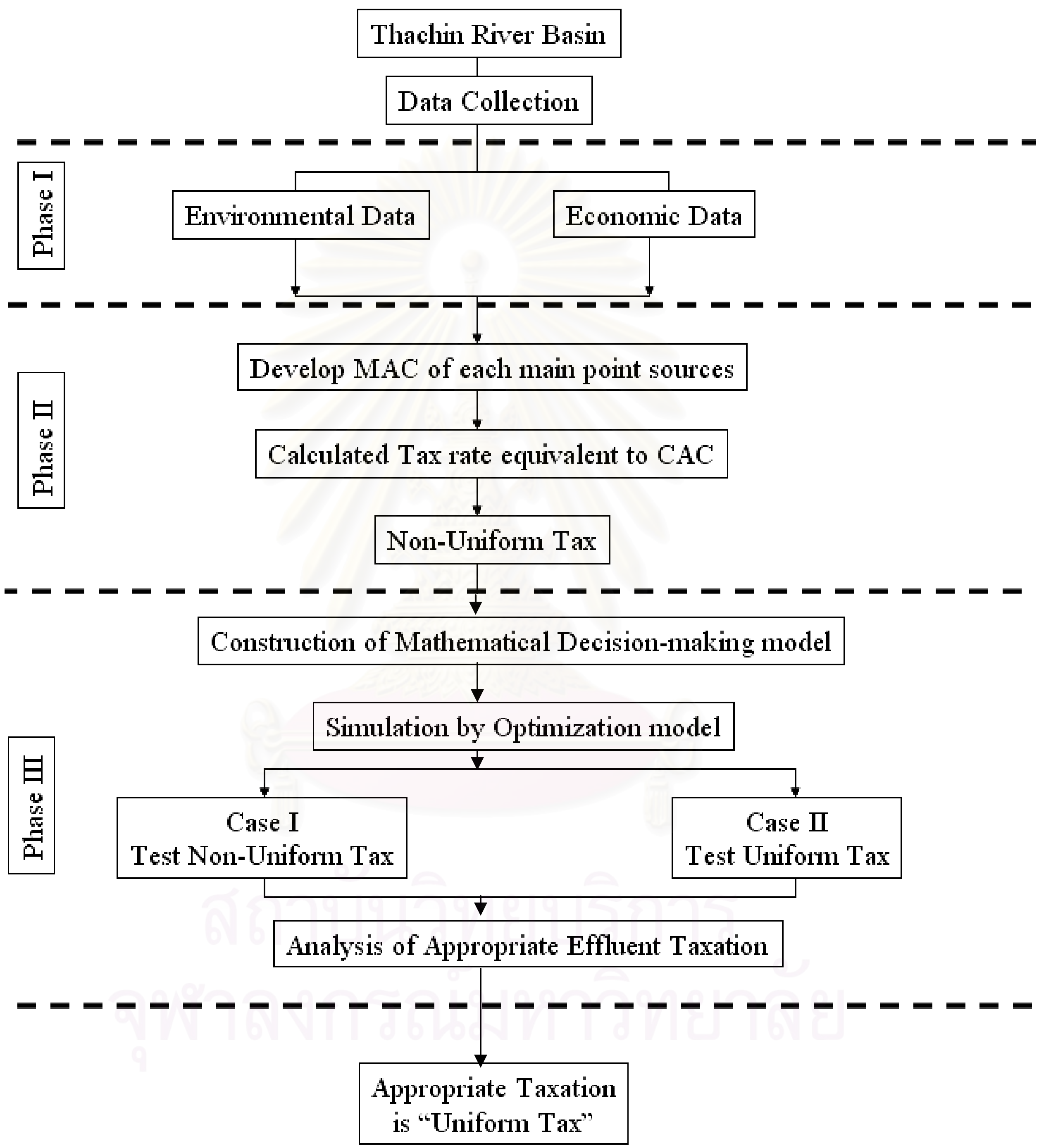

Figure 1-4: Conceptual Framework

The steps in estimating the Appropriate effluent taxation are briefly described:

The first phase is to collect the data which divided into 2 aspects which are Environmental aspect and Economic aspect. First aspect is the actual information of Environmental aspect which is concerned with pollution characteristic, carrying capacity, Total Maximum Daily BOD Loading, and Target of emission reduction of Thachin sub-basin. Second aspect is concerned with the production cost, abatement cost and the revenue of every activities in Thachin sub-basin. From these information are using continuously in Phase II and III.

Second phase is the calculation of the marginal abatement cost (MAC) of each main point source and calculate the emission tax rate under Command and Control (CAC).

Third phase is the construction of the Mathematical Decision-making model and simulated by using optimization model for arriving appropriate emission tax charge.

CHAPTER II

LITERATURE REVIEW

2.1 Thachin River

The Thachin river basin covers a total area of 11,763 sq. km. or 7.35 million rai, consisting of 9 provinces, i.e., Chai Nat, Uthai Thani, Suphanburi, Kanchanaburi, Nakhon Pathom and Samut Sakorn covering approximately 11,706 sq. km. or 99.5% while 57 sq. km is located in the remaining three provinces, i.e., Ayutthaya, Nonthaburi and Bangkok.

The details are shown in the table below:-

Table 2-1: Percentage and ratio of each province in each sub basin of Thachin River

Sub-basin	Province	Area of Province		Ratio	Ratio	District Name
		Total area	Basin area	Province in Basin (%)	Area in Basin (%)	in Province
Upper	1. Chainat	1,541,681	736,356	47.7	10	Muang, Sankhaburi, Han Kha, Wat sing,
	2. Uthaithani	4,161,896	671,368	16.1	9.1	Ban Rai
	3. Suphanburi	3,378,300	1,678,875	49.7	22.8	Don Jadi, Sam Chuk, Dan Chang, Nong Yasai, Sri prajan
	4. Kanchanaburi	12,116,415	471,237	3.89	6.4	Lao khwan
Middle	5. Suphanburi	3,378,300	1,246,337	36.9	16.9	Muang, Song Pri Nong, Bang Pra Ma, U thong
	6. Kanchanaburi	12,116,415	638,562	5.3	8.7	Panomthom, Huai kra Chao, Bo Phloi
	7. Ayutthaya	1,591,470	14,662	0.92	0.2	Lat Bua Luang, BangSai, Pakhai
	8. Nonthaburi	404,858	3,600	0.9	0.05	Sainoi
	9. Nakhon Pathom	1,317,218	1,004,287	76.2	13.6	Kamphaeng Saen, Don Tum, BangLen, Muang, Buddha Monthon, Nakorn Chai Sri
Lower	10. Nakhon Pathom	1,317,218	312,931	23.7	4.3	SamPhran
	11. Samut Sakorn	556,718	556,718	100	7.57	Ban Phaeo, Krathum Ban
	12. Bangkok	984,822	177,162	1.7	0.23	Bang Khun Thain

Source: PCD, (2005a)

Thachin River is a major river known under many different names depending upon the location through which it passes, such as KlongMakham, Suphan River, and

Nakornchaisri River. However it is commonly known as the Thachin river. The origin of the Thachin River is a tributary of the Chaopraya River which separates at Khong Makham, Makhamtao Subdistrict, WatSign District, Chainat Province and passes through many provinces including Chainat Province, Suphanburi Province, Nakon Pathom Province and downstream in Samut Sakorn Province before flowing into the Gulf of Thailand. This gives a total length of approximately 325 km.

The average depth of Thachin River is approximately 5.30 to 11.50 m. Upstream in the area of Khong Makham up to Khong Phayabunlo the average depth is 6.00-6.50 m. and downstream from Bann Banghuang to Samut Sakorn Province the average depth is 7.50 – 11.50m. The average width of Thachin River is approximately of 46-500m., the narrowest part of the river being less than 100 m. between Wat Bang Mae Mae, Bang Pra Ma District, Suphanburi Province and upstream to the origin of Thachin River located at Mak Hamtao sub district, Wat Sing District, Chainat Province. The Thachin River is wider than 200m. downstream between Mahasawat Watergate to river mouth, PCD (2005a).

Evidently, the hydrology of the Thachin is no longer characteristic of streams in tropical regions as the inflow is controlled by the regulatory structure on the Chao Phraya River just downstream of the diffluence junction. Consequently, the average monthly discharge throughout the year varies from about 50 m^3/s to 290 m^3/s with the average annual flow being about 75 m^3/s.

There are several water gates regulating the flow throughout the river's course. As the catchment is mostly on a flat plain, the stream gradient is minimal and the water level in most of the lower half of the watercourse is affected by tidal fluctuations. As stated earlier the Thachin River has the dubious distinction of having the worst water quality in Thailand. This situation is mostly due to the excessive discharge of waste and pollution into the river, resulting in water quality being far below the standard level set for inland water quality, especially along the lower and middle reaches of the catchment. The capacity of the stream to absorb these pollutants is also constrained by flow regulation which limits the natural flushing of the stream. Another important factor is the ponds and local water storage on the flood plain which are prone to overflow or washout during heavy rainfall periods causing a crisis scenario as experienced in 2001.

The Sub-basin of Thachin River

The sub-basins of the Thachin river are either natural creations or man-made to be used for irrigation and/or flood prevention systems. There are 36 major canals along the Thachin River:

- 2 canals connecting between the Thachin river and Mae Khong River are the Damnoen Saduak Canal and the Bang Kaew Canal
- 21 canals connect between the Thachin River and ChaoPhaya River such as the Bang Pra Ma Cannel, the Chaojed Cannel, the Prayabunloe Cannel, the Prapimon Cannel, Mahasawad Cannel, the Prasricharoen Cannel, etc.

The Thachin river can be divided into three segments according to the water quality classification as follows:-

Segment 1: Thachin River from the river mouth at Muang District, Samutsakorn Province (Zero Kilometer), going up north to the front of City Hall of Nakornchaisri District, Nakornpathom Province (82^{nd} Kilometer). This segment is classified as class 4

Segment 2: from the front of City Hall of Nakornchaisri District, Nakornpathom Province (82^{nd} Kilometer), going up north until reaching Prothipraya watergate at Muang District , Suphanburi Province (202^{nd} Kilometer). This segment is classified as class 3

Segment 3: from Prothipraya watergate at Muang District, Suphanburi Province (202^{nd} Kilometer), going up north until reaching the origin of Thachin river at Ban Pakklongmakamtao, Makamtao Subdistrict, Chainat Province (325^{th} Kilometer). This segment is classified as class 2.

The report of Pollution Control Department (2005a) shows that the water quality in Thachin River has continuously deteriorated using the BOD and Dissolved Oxygen as indicators. The data indicates that the BOD exceeds the standard limit, which is :-

not exceeding 4.0 mg/liter for the lower segment,

not exceeding 2.0 mg/liter for the middle segment,

not exceeding 1.5 mg/liter upper segment.

2.1.1 Total Maximum Daily Loading and Target of emission reduction

PCD (2005a) found that the problems of water resources have been continuously deteriorated due to the carrying capacity are incapable to receive the load of activities such as agriculture and especially industry. The activities of industry need a load of water which generates the wastewater as well. The wastewater from industry has highly contaminated with organic matter and non-organic matter; however, the control pollution act has been compelled the manufactures treat their waste in the standard compulsory. The controlling emission standard has been considered only the effluent loaded-concentration but unaware of effluent loading lead to the volume of effluent excess than the carrying capacity. The solution of this problem is to control the pollutant sources by limiting the effluent volume to match the carrying capacity. Each of basins has different capacity to receiving the pollutant. From Ministry of Science, Technology and Environment Issue 3 (B.E 2539) appointed to define the effluent standard for the pollutant generators in industrial park.

At present, there is no control for the volume of pollutant emission into the receiving water resources. Thus Pollution Control Department urgently studied the way to control the effluent volume and process to effluent from the industrial pollutant generators. It used for improving the effluent standard of industrial and the water surface quality standard which include the processing of permit system for pollution emission. The purposed of their project fined the suitable effluent volume and implemented the procedure for industrial pollutant generators which emitted the suitable volume of pollutant for the water resources and increased the effluent standard and surface water standard. The expected result of their project was to know the volume of the effluent and the procedure for controlling the effluent from the industrial generators sources and other pollutant sources.

2.1.2 Economic of significant pollution activities

2.1.2.1 Pig Farm

Nowadays, the numbers of pig farms are increasing which some manage to treat their waste before discharge into the environment but many of them have not. Therefore, the government agencies were gathering data, analyze and manage the wastewater from pig farm in order to control the effluent load into the water resources. However, the government would like to study the affect of farmers and entrepreneurs after applying the regulation.

The government assigned the CMS Engineering and Management to study the development and methodology for controlling the pollutant water in order to purpose to the PCD, (2003a). The purposes of their project were as follows:

1. Making database of pig farm in Thailand by searching and listing all pig farms in details such as name of the pig farm and their located.
2. Planning for managing the pig farm wastewater by concerned in legal matter, regulation which related to the economic and social aspects.
3. Providing the instruction of technology to manage pig farm.

The scopes of work of the project were to gather, analyze and study about its information. They studied the methods and procedure to eliminate the wastewater from pig farm and provided the instruction manual to manage the pig farm.

2.1.2.2 Urban community

Two decade, Thai government spent 67,290 million Bath for treatment facilities; however, the expenses of running treatment system are high and most local governments have inadequate budget to run fully capacity of treatment.

PCD (2003b) assumed that if local government could collect the effluent tax charge, it would be used and covered all the expense for managing the treatment system and investing in expanding facilities.

2.1.2.3 Aqua culture

PCD (2005b) main target was to manage and prevent the effluent of Aqua culture the details as follow:

1. Demonstrated farm which manage and treat the effluent pollutant to satisfy the effluent standard.
2. Provide manual and implement the methods to eliminate the polluted water from aqua culture.

The scopes aimed, firstly, to reduce the effluent pollutant and introduce the proper management scheme and technology in order to eliminate the polluted water and the effluent pollutant.

Secondly, the study provided and tested the prototype treatment system in the laboratory. Thirdly, it also designed and tested the treatment system in the aqua cultural area by evaluating its efficiency, farm management, treatment system and the cost of operation.

The expected results from the study are to reduce the effect to water resources from the effluent and its sediment from the aqua culture and implement the methodology for farmer and local office to follow in order to get rid of the waste water of aqua culture.

2.1.2.4 Industry

The purposed of PCD (2003c) aim to draw the tools for pollution control officer to indict the pollutant generators who smuggle to drain the waste water or do not use treatment system. The target of this research is defined the charging rate in order to use its against the pollutant generators. The expected results of their project are to control and monitor the pollutant generators to emit the pollutant water not over the standard limits. The scopes of their work are firstly, gathering data and analysis. Secondly, to study, analyses and finding the cost of operation. Thirdly, to provide software which use for calculating the daily charge rate for treatment system. Fourthly, to arrange the implement meeting one time that needs the participants at least 80 persons to attended the meeting. Fifthly, to use the results of (1) and (2) in order to provide the manual for officers who control the pollution.

2.2 Existing Regulation in Thailand

The effective regulations to control water pollution in Thailand can be divided into 2 categories:-

1. Regulations to control the source of polluted water by defining the polluted water which discharges effluent.
2. Regulations to preserve the quality and utilize the water resources which can be subdivided into regulations to preserve the water resources and assigned to the local authorities responsible for their own regulations in order to preserve their local water resources.

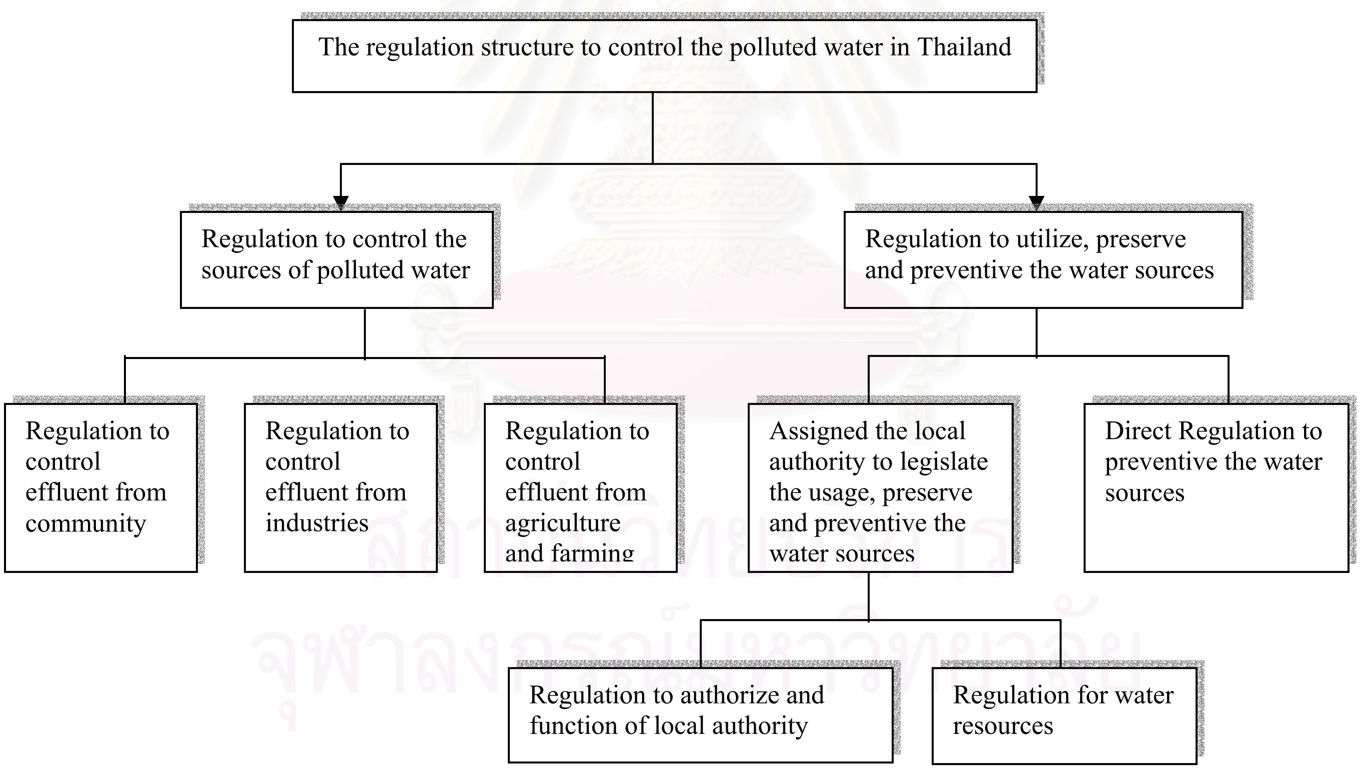

Figure 2-1: The regulation structure to control the polluted water in Thailand
Source: PCD, (2005a).

2.2.1 Regulation to control sources of polluted water

At present, Thailand has regulations which are to be applied in the control of effluent sources consisting of 3 categories including :-

(1) urban communities/built up areas

(2)agriculture and

(3) industry.

The details are shown in the table below:

Table 2-2: Regulation and Constraint of each polluted water resource

Type of polluted water	Regulation and Constraint
Urban area	**Building**
	1. Regulations from Ministry of Sciences, Technology and Environment designated to the type of building in order to control the effluent of polluted water into public water resources and the environment.
	2. Regulations from Ministry of Sciences, Technology and Environment designated to the type of building to control sources of polluted water into public water resources and/or environmental concerns 2 (B.E 2538).
	3. Regulations from Ministry of Sciences, Technology and Environment designated to the standard of effluent depending on the type and size of buildings.
	Allocated land
	4. Regulations from Ministry of Sciences, Technology and Environment designated to allocated land that are potential pollution generators and the effluent into public water resources and the environment have to be controlled.
	5. Regulations from Ministry of Sciences, Technology and Environment Issue 5 (B.E 2539) designating the standard of effluent for allocated land.

Table 2-2: (continued)

Type of polluted water	Regulation and Constraint
Industrial	1. Regulations from Ministry of Industry Issue 2 (B.E2539) designated to the effluent standard for industries.
	2. Regulations from Department of Industrial designated to the specification of effluent emissions which are different from the those from the Industrial Department.
	3. Regulations from Ministry of Industry issue 13 (B.E 2525) act B.E 2512 designated to the function of industrial licensees.
	4. Regulations from Ministry of Industry issue 22 (B.E 2528) act B.E2512 appointed to the function of industrial licensees..
	5. Regulations from Ministry of Sciences, Technology and Environment Issue 3 (B.E 2539) designated to the standard for controlling manufacturing emissions and industrial park emissions to water resources.
	6. Regulations from Ministry of Sciences, Technology and Environment Issue 4 (B.E 2539) designated to the control of manufacturing and industrial park effluent into public water sources and environment.
	7. Ministerial regulation, issue 2 (B.E 2535) prohibits the manufacturers to emit emissions, except those which satisfy standard limits.
	8. Ministerial regulation issue 3 (B.E 2535) designating harmful manufactures of the environment, in order to provide reports of pollutant loading
	9. Ministerial regulation issue 5 (B.E 2535) appointing details and procedures for factory licenses.
	10. Ministerial regulation issue 11 (B.E 2535) appointing to manufactures equipped with wastewater treatment systems, who have to install measuring equipment in order to report the volume of effluent.
	11. Regulations from Department of Industrial Work appointed to provided effluent reports.
Agriculture	1. Regulations from Ministry of Sciences, Technology and Environment appointed to the effluent standards for pig farms.

Source: PCD, (2005a).

2.2.2 Regulations to preserve the quality and utilization of water resources

The regulations to preserve the quality and utilization of water resources can be divided into 2 categories which are (1) direct regulations to preserve water sources and (2) the local regulations which are designated by responsible local authorities.

Table 2-3: Regulations to preserve the quality and utilization of water resources

Directed regulation to preserve the water resources	**Regulation for decentralize to local authorities to issue their own regulation**
Support and preserve the national environment Act (B.E 2535)	Regulations for responsibilities and authority of local authorities
Preservation Canal Act	- Constitution of Kingdom of Thailand B.E 2540
Royal Irrigation Act (B.E 2485) and order from	- Municipality B.E 2496 (corrected issue 11 BE 2543)
Royal Irrigation department 883/2543	- Local council and Local administrative B.E 2537
Protect water supplies/ Canal Act (B.E 2526)	-Provincial Administration Act B.E 2540
Fishery Act (B.E 2490)	Regulations for water resources
Underground Water Act (B.E 2520)	- Promotion and Environmental Quality Control Act B.E 2535
Navigation in Thai Territorial Waters (B.E 2456) and	- Public Health Act B.E 2535
Harbor Department 67/2534	
Public Health Act (B.E 2535)	
Criminal Code	

Source: PCD, (2005a).

2.2.2.1 Directed regulation to preserve the water resources

Table 2-4: Directed regulation to preserve the water resources

Regulation	Detail	Constrain to control waste water
Supported and preserved Environment B.E 2535	This act gives authorization to the Minister in order to appoint the control of effluent sources type which are not to exceed the standard limit, Act 56, for water resources or other regulations which are specially issued by governors to control polluted water Act 69 to whom pollutant generators have to install waste water treatment systems Act 70. The penalties to those who have omitted to treat the waste water or illegally discharged effluent into public water resources. Act 92 in case of pollutant generators omitted or illegally discharged effluent into public water resources have to be fined on a daily basis at 4 times the rate of the expenses to run the waste water treatment system. Act 96 the pollutant generators have to be responsible for all expenses for the government to clean up the waste water from the public water resources and responsible for the cost of environmental damage.	Although this act have been defined the legal punishment for the waste water generators who spread harmful polluted to the public health or damage to the private or states properties or damaged to the environment. From Act 96 and 97 the fine will be charged for waste water generators but there is no clear procedures and conditions.

Table 2-4: (Continued)

Regulation	Detail	Constrain to control waste water
Canal Act B.E. 2536	This act defines the legal punishment to those who dispose garbage or trash into the canal and are to be fined not over 20 Bath or imprisoned not more than a month or both penalties.	Not a severe punishment.
Royal Irrigation Act BE 2485	This act is issued in order to support and control the Royal Irrigation and heavily punish those violating the law by poisoning or contaminating the Royal irrigation rather than dumping garbage. Thus, prohibition to contaminate or poison the Royal Irrigation. Act 35 Punishment for violations gives up to 3 months prison sentence or a maximum 2,000 Baht fine or both.	Punishment of chemical effluent into water resources harmful to agriculture and consumers.
Order from the Royal Irrigation Department 883/2532 at 19 Dec 2532	To prevent and improve the poor quality effluent to irrigation and other water resources which are concerned by irrigation in irrigation areas.	Appointed to control the effluent in irrigation and other water resources which are concerned by irrigation in irrigation areas.

Table 2-4: (Continued)

Regulation	Detail	Constrain to control waste water
Navigation in Thai water Territory B.E 2546	The purpose of this Act to protect the people along water routes and prohibit obstruct of the same route. Acts were added and corrected in BE 2535 in order to preserve the water environment. Consequently, Act 119 Prohibits dumping rock, sand, dirt, mud, oils and other chemicals into the river, canal, reservoirs and lakes which are the route for traveling by boat to the sea in Thai territory leading to sea shallows except those permitted by the Harbor Department. The punishment for violations are 6 months imprisonment or fines not more than 10,000 bath or both and payment of clean-up operations.	Not a severe punishment
Announcements from Harbor Department 67/2534 at Feb 20, 2534	Appointed to allow all types of effluent into the river.	-
Public Health Act BE. 2484	This Act gives authorization to the local officer who is responsible for removing, prohibiting or stopping	The local officers able to follow the process of laws are stated in the Act

Table 2-4: (Continued)

Regulation	Detail	Constrain to control waste water
Criminal Code	Act 237 To whom poisoning or deposing any harmful chemical to contaminate water resources, wells, ponds which are provided for publics consumption. The punishments are 6 months to 10 years imprisonment or both. Act 380 To those generating the waste water drainage into the water supply will be fined and imprisoned for not more than 1 month.	This Law stresses the contamination of water resources harmful to the public and specifically provides water resources for public consumption such as ponds and reservoirs.
Cleaning and Ordering of Nation BE. 2535	This issue prohibits anyone deposing dirt, garbage or anything on the road, water which issue in Act 33 and authorized the local authorities to give a warning to the guilty person to get rid of the waste Or arrest and fine the person who violates the law from Act 44 to 46 and 48.	Not severely punished.
Preservation Water supply canal Act B.E 2535	Purpose of this law is to preserve natural water resources for the water supply by prohibiting the extraction of water from canals or canals expanding or canals with leaks.	Concerned about special protection for raw water resources which are used for the water supply only and severely punishment.
Fishery Act B.E 2490	Purpose of this law is to protect aquatic animals and water resources for fisheries by prohibiting drainage or any activities harmful to aquatic animals or harvesting of aquatic animals	Not severely punished in proportion to the extent of damage.

Table 2-4: (Continued)

Regulation	Detail	Constrain to control waste water
Underground Water Act B.E 2520	Act 6 gives authorization to the Ministry	Only concerned with the protection of underground water.
Industrial Ministry Issue 5 (B.E 2521) follow from Underground water Act B.E 2520	Specifies regulations and conditions for draining water into underground water wells.	-

Source: PCD, (2005a).

2.2.2.2 Regulations from local authorities to preserve local water resources

A) Regulations concerned with authorization to the local authorities

Table 2-5: Regulation from local authorities to preserve local water resources under local authority jurisdiction

Principle	Act
- The constitution of Kingdom of Thailand	Act 78 government has to decentralize to local authorities decisions for their own activities. Act 79 government permits and support the people to preserve and eliminate pollution which is harmful to health, safety and quality of life. Act 290 Local organizations have authority to follow the regulation as follows (1) Management Maintenance and utilize the natural resources and environment in the surrounding area.
- Municipality Act B.E 2496 (corrected and added issue 11 B.E 2543)	Act 60 Municipal government has the power to legislate but not to be in conflict with the law in the following cases (1) To operate on the duty of municipality (2) The Municipal responsibility is not to cover the preservation and prevention natural resources and environment, however, duty of municipality which states in regulations and other duties in the regulation are the duty of the municipality

Source: PCD, (2005a).

B) Regulations concern with water resources

Table 2-6: Regulation from local authorities to preserve local water resources concerned with water resources

Principle	Act
- Act of Provincial management organization B.E 2540	Act 45 Provincial management organizations have a duty as follows:- (1) Legislation of laws but not against the law (2) Prevention and preservation of natural resources and environment Act 51 legislate in the case of (1) Operated on the duty of Provincial management organizations (2) Allows the Provincial management organization to legislate fines and imprisonment of offenders but not fines over 500 Baht.
Support and Preservation the quality of environment Act	Act 60 the local official in the polluted control area according from Act 59 to provided the operation plan in order to reduce and get rid of the polluted in the control area and purposed to provincial governor (3) To study, analyze and evaluate the pollution including the effect to the quality of environment in order to prevent and reduce the pollution in the controlled area.
Public Health Act	Act 26 gives authorization to the local officer to prevent and preserve the water resources such as canals and other places in their controlled area.

Source: PCD, (2005a).

2.3 Case studies of other countries controlling water effluent

From the literature review, there are apparently 2 formats to control the effluent sources as follows:-

Format 1: To control the concentration-based effluent standard which Thailand is implementing at present.

Format 2: To control the load-based effluent standard, this has a case study in each format as follows

2.3.1 Control the effluent sources by controlling the concentration-based effluent standard

This format type is to control drainage of the sources by the concentration-based effluent standard which allows every type of polluted water source. The effluent discharges into the environment without considering the limited receiving capability of the river/water body which is not able to manage the pollution load. Consequently, in some areas the expansion of industrial and community areas are increasing due to development pressure, which are not confined to the central city. As a result, the water resources are highly contaminated as they receive the excess of wastewater loading. The countries have similar types of effluent control as Thailand are Singapore, Malaysia, Vietnam and Laos. However; there are differences defining the obtaining of the source standard and the concentration-based effluent standard.

2.3.1.1 Singapore

Singapore is the smallest country in South East Asia with high population density, the highest standard of living and education and a fully developed hi-tech. economy. The land area is 637 sq. km. and a coastline of 193 km. In 1950, a population of about a million people with a daily water demand of 142,000 m^3 grew to 4 million by 2004 and its daily water consumption is 1.4 million m^3 . This is expected to grow by a third in 10 years. Therefore, while the population has grown by about 4 times, water demand has risen more than 9 times. Households account for 55 percent of Singapore's water consumption. Singapore now gets nearly half its drinking water from rainfall in well designed catchment's areas, with the plan that all feasible land would have to be used. Rainfall supplies approximately 50% of Singapore's water; the remainder is mainly imported from Malaysia. Presently, most catchment's areas have facilities to recycle water or desalination plants are being built.

Pollution was recognized as a problem since the 1960s, and significant steps have been taken since to alleviate industrial and urban pollution. The Ministry of Environment

(ENV) was first established in the 1970s as a department within the Prime Minister's Office before eventually becoming a full-fledged Ministry. It is responsible for providing the infrastructure for waste management, as well as enforcing and administering legislation relating to pollution control and public health. The Pollution Control Department (PCD) within the ENV is in charge of environmental planning and building development control, air and water pollution control and the regulation of hazardous substances and wastes. Due to the government's strong commitment to pollution control and also to Singapore's small size, the ENV has been largely successful in implementing its pollution control programs throughout Singapore.

However, the Singapore Constitution does not contain any provisions on the environment. Neither does Singapore have a framework law on environmental protection and management. There is no mandatory environmental impact assessment (EIA) system laid out in legislation. The present scheme of environmental management in Singapore is scattered throughout numerous Acts and Regulations. EIAs are required on an ad hoc basis at the discretion of the ENV. There have not been many judicial pronouncements - in fact, environmental litigation/court cases are almost unknown. The environmental protection effort in Singapore is almost exclusively administrative in nature - the relative success of environmental management in Singapore is primarily due to the administrative efficiency of the ENV and other government agencies operating within a relatively tiny country.

The receivable wastewater sources are defined into 3 categories such as sewage, general water resources and raw water sources use for treating for the water supply. The standard effluents of commercial types are shown in table 2-7. Based on the standard effluent of the industrial type which are effected at present, the standard of concentrated-based of effluents in Thailand is the same as the standard of effluent into the raw water resources for making water supply such as BOD, oils/fats and others harmful chemical compounds.

Table 2-7: The standard drainage in commercial zone of Singapore

Parameter	Drain	General water resources	Raw water for water supply
1. pH Value	6-9	6-9	6-9
2. BOD (5days at 20 C	400	50	20
3. COD	600	100	60
4. Total Suspended Solids	400	50	30
5. Total Dissolved Solids	3000	2000	1000
6. Grease and Oil	60 (Hydrocarbon) 100 (Glycerides of fatty acid)	10	5
7. Metals in Total	10	1	0.5
8. Phosphate (as PO_4)	-	5	2
9. Nitrate (as NO_3)	-	-	20

Source: PCD, (2005a).

2.3.1.2 Malaysia

In Malaysia the receiving pollutant water resources can be divided into 2 groups. Table 2-14 indicates the standards for effluent. The standard of group A for effluent to the water basins. Group B for effluent into the surface water. A comparison for industrial effluent in Thailand are categories in group A. The standard of others concentrate-based effluents are more strictly than the standard in Thailand such as BOD, oil/fats/grease etc.

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Table 2-8: The standard industrial effluent in Malaysia

Parameter (mg/l)	Maximum Effluent	
	Standard A	Standard B
pH (units)	6.0-9.0	5.5-9.0
BOD5 at 20 C	20	50
COD	50	100
Suspended Solids	50	100
Oil and Grease	Not detectable	10.0

Source: PCD, (2005a)referred to Environmental Quality (Sewage and Industrial Effluents) Regulations 1979.

The standard pattern to control effluent sources is defined by the maximum concentration pollution which are allowed for draining, are divided into 2 formats which are concerned by the strict level of standard depending upon the receiving pollutant water resources and type of industry which are the same format in Thailand. However, the drainage standards of industry in Thailand are affected at present, especially for BOD by the highest level of quality of water resources use for consumption. Recently, Thailand is facing to the continuous decline in quality of water resources. Consequently, the polluted sources are controlled by concerning on the concentrate-based effluent only without considering the maximum carrying capacity of water system due to pollution loading. The water system or river could have limited capacity to receive pollution loading without effect to water quality which would protect the declining quality of water resources especially the development of river basin is rapidly expanded and discharges wastewater sources in Thachin basin, PCD (2005a).

2.3.2 Load-based effluent standard

The load-based effluent standards to control the polluted sources have water quality-based effluent limits for each type of polluted source which takes into consideration the water treatment technology. The water quality-based effluent limits depend upon the capacity of water resources to adsorb the polluted water. Examples of the controlling water quality-based effluent limits for each type are as follows.

2.3.2.1 Water quality-based effluent limit for each type of pollution source

The water quality-based effluent limits for each pollution source, without concern for the capacity of water resources to receive polluted water, are not equal. Each locality is concern by the Best Available Technology (BAT) to treat the load-based effluent per unit of each polluted source which leads to the specific standards of water quality-based effluent for each type of pollution source.

For example, the control of water quality-based effluent implemented in India which has a load-based effluent standard from the industrial sources, is classified into 2 formats:

1) Concentration-based effluent standard and load-based effluent standard for certain industries, however the quantities of polluted waters are limited for some industries.
2) Load-based effluent standard are using for 3 types of industry such as Oil refinery industries, large pulp and paper industries and newspaper printing industries shown in table 2-9

The limited quantity of polluted water from industries can be divided into 9 types such as integrated iron & steel, sugar industries, pulp & paper industries, fermentation industries, caustic soda, textile industries, starch, glucose, dairy, natural rubber processing industries and fertilizer shown in table 2-9

Table 2-9(a): Load-based standards in India

Parameter	Oil Refinery (unit : kg/1000) Tones of crude Oil processed	Paper Pulp and Printing Industrial
Oil & grease	10.0	-
Phenol	0.7	-
BOD	10.5	-
Suspended Solids	14.0	-
Sulphide	0.35	-
Total Organic Chloride (TOC)	-	2.0

Source: PCD, (2005a).

Table 2-9(b): Quantity of pollution water from certain industries in India

Seq.	Industrial Type	Standard
1	Integrated Iron & Steel	16 m^3 /tons of finished steel
2	Sugar	0.4 m^3 /tons of cane crushed
3	Pulp & Paper Industries (i) Pulp & paper (ii) Rayon grade pulp	 175 m^3/tons of paper produced 150 m^3/tons of paper produced
4	Textile Industries: Man-made fiber (i) Nylon & Polyester (ii) Viscose Staple Fiber (iii) Viscose filament Yarn	 120 m^3/tons of fiber produced 150 m^3/tons of product 500 m^3/tons of product
5	Starch Glucose and related products	8 m^3/tons of maize crushed
6	Dairy	3 m^3/kl of Milk

Source: PCD, (2005a).

2.3.2.2 Water quality-based effluent limits

Case studies of foreign countries such as the United States of America, the European Union (EU) and Australia are given below :-

USA.

In USA, since the declaration of water qualities act in 1965 the Federal Water pollution Control Agency (FWPCA) was established which had authorization to control the standard of polluted water. From 1971 this organization has been changed to Environment Protection Agency (EPA) and has more responsibility to study and do research on national environment policy. However, preventing water pollution and protecting water resources are major concerns. Until 1977, this act has been called Clean Water Act or CWA which has 4 major concerns as follows:

- The polluted water draining into water resources have no privacy right as drainage into public water resources needs permission.
- The permission for draining has to be defined based on the control of the quantity of polluted water.
- The polluted water has to treat with the best treatment technology which is suitable for the economy and receiving pollutant water resources.

- The quantity of pollution that has been allowed to drain might be more strictly controlled than the standard limits to preserve and satisfy the standard of quality of water resources.

In order to achieve the target of this Act, the procedure for permission to drain out the pollution has been implemented which is called National Pollutant Discharge Elimination System (NPDES). It is a tool for local government to control the drainage polluted water into water resources. However, the NPDES system does not cover non-point sources.

National Pollutant Discharge Elimination System (NPDES)

NPDES controlling system, enables the local authorities to arrange the plan and a procedure which leads to the implementation for preserving the standard quality of water called "Total Maximum Daily Loading", (U.S.EPA.). The proposals has to be sent to Environment Protection Agency for approval and permission to implement the plan.

The regulations to set up TMDL are as follows:

- The water resources having pollution problems are on the list of WQA 103.31 (a) and has to arrange the TMDL.
- TMDL has been arranged in order to prioritize the water resources
- TMDL has to identify the essential level in order to preserve the standard quality of water resources.
- TMDL includes the following details:-
  1. Name and location of the water resources having a problem of water pollution including the sub-basin and its network of the water resources which has been contaminated and the water quality affected.
  2. Types of pollutant load which are arranged for TMDL and the ability of receiving pollutant water resources to take the maximum pollutant load without affecting the water quality.
  3. Identify the quantity of pollutant load which the water resources have received.

4. Classify type of polluted sources which have allowed a certain amount of pollutant load to drain into the environment.
5. Identify the quantity of pollutant load for Point sources such as industry and urban communities which are allowed to drain under the Clean water Act and identify the quantity of pollutant load of Non-point sources such as rain water from abandoned mines, farming, which are permitted to drain. For other polluted sources, such as natural resources, it is unnecessary to identify the quantity of pollutant load. Indicate the technical analysis summary to show that if the control pollutant load has been arranged within the standard limit, the quality of water resources are within the standard limit.
6. Identify the safety value in order to calculate the maximum pollutant load without affecting the water quality.
7. Seasonal variations effect the ability of receiving pollutant water resources to take the maximum pollutant load without affecting the standard water quality limit.
8. Predict the change of pollutant sources which increase or decrease of pollutant in the future.
9. Implement TMDL

Taking the TMDL which has been approved by the EPA in order to implement in local area, the local environmental organization has full responsibility to implement the plan by controlling the pollutant sources that have been identified by TMDL. These organizations are capable to drain out the pollutant load into the environment by using a permit system which is covered by the WCA Act.

Wastewater Discharge Permits

Wastewater Discharge Permits are legal documents using for the organization that has a duty to permit someone to drain wastewater into the environment. The organization chart is shown in Figure 2-20. Beginning with the concerned organization receiving the application. The officer reviews the application for completeness and accuracy. The calculation has to be made in order to find the quantity of pollutant load to be allowed to drain off by considering the technology-based effluent limits. Considering the water quality-based limits; however, the quantity of pollutant load in licenses is the highest strict level under monitoring requirements and other special conditions. After conducting review processes, it finally becomes a draft or proposed permit and lastly final permit can be issued.

European Union (EU) - Europe

(Kampus et al., 2002)In the European Union (EU), water quality is a major concern for environmental policies as can be seen by the numerous Directives that, either directly or indirectly, deal with water policies. The `first series' of EU water legislation began in 1975 with the Surface Water for Drinking Directive (75/440) which coincided with the First Action Programme on the Environment. Then followed, water quality standards which were set through various Directives, such as: bathing waters (76/160); fresh waters (78/659); shellfish waters (79/869); and drinking water (80/778). The `second series' of water legislation includes the Nitrate Directive (91/676) and the Directive for Integrated Pollution and Prevention Control (96/61).

However, in the 1990s the increased awareness of European citizens and other concerned parties for water quality obliged them to push for the recent policy reform under the Water Framework Directive (WFD), which aims to unify, bring together and co-ordinate the rather fragmented structure of water policies in the EU. The WFD increases the range of water protection to all waters, surface waters and groundwater and will try to address water policy and water management in a more effective and consistent manner.

The main innovations of the WFD are at two levels. First, the emphasis is placed on river basin (catchment) as the appropriate unit of management, which is very different from the approach on administrative or political boundaries. Second, the `combined approach' of reaching `good status' for waters by setting emission limits and ambient quality. Reaction to the WFD from the different member states (15 countries in 2000 and 25 in 2006) is of course, very different. However, these directives do not necessarily mean than the various European governments will carry out and implement effective measures.

As a result, in Denmark, the new WFD is considered as inadequate as member states are not OBLIGED to implement the recommended measures – therefore, the Danish government prefers to maintain it's own standards for water quality, while respecting WFD recommendations.

On the other hand, Poland, a new member state (post-communist state, relatively low standard of living and a large population, 45 million) which has inadequate water treatment facilities combined with 'old technology' dirty-polluting industries and low societal environmental awareness (Polish people are more interested in making money and having a higher standard of living equal to Germany and France) is asking for considerable financial and 'know-how' assistance in beginning to implement some of the more basic recommendations of the WFD.

Therefore, in the Europe (EU), the control of drainage has been set up by maximum emission standards and the water quality standards. The member states of the union have in theory to follow the standards strictly. Moreover, water quality is to be managed on a catchment/basin approach to the issue of permits.

The European Union are also highly concerned by the receiving pollutant water resources which the quantity of pollutant load discharges into the water resources and does not affect the ecosystem (Ecosystem-based permitting system).

The details and procedures for controlling the emission of the members of European Union are indicated as follows:

Table 2-10: Comparable table of controlling source pollution emission between European and United States of America

Implementation	European	USA
Policy and target of demanding pollution deduction	Central Government	US.EPA
Government agency target to reduce quantity of pollution from each pollution sources	Central Government	Environmental States Agency
Pollution generating sources	Factory (Waste water 50 cu.m/day)	Type of Point source - Industrial - Urban Community - Farming
Reduced the pollution from the non-point sources	Promote and Support small factories and households to reduce the pollution in locally	Local government control pollution from the non-point sources by Best Management Practices (BMPs) propose to the EPA and Budget

Source: PCD, (2005a).

The EU has arranged for member states to reduce water pollution problems which cause hazardous substances by following the agreement:

1) Maximum emission standards for hazardous substances
2) Water quality goals

In order to control the problem of polluted water, the EU has arranged the procedures as follows:

1) The permission of effluent pollutant water into water resources have to cover the pollutant sources in direct or indirect water discharges.
2) Permission to drain into water resources has to respect all the emission standards.
3) Permission has a period of time for 4 years or 5 years.
4) Evaluation has to be made every 4 years
5) Evaluation has to report the pollutant quantity which allowed to is drain off

However, the emission pollutant standard is based on the water quality standard. In 1996, the EU has used the integrated pollution prevention and controlled directive for industry and processing of permission has to concern the IPPC.

In 2000, the EU admitted to the pollution prevention to the water resources which is called European Environmental Framework Directive (EEFD). To specify the production type and management in order to satisfy the EU standard, which controls the polluted sources in types of point source and non-point source.

1. The EU prohibits the use the harmful chemicals.
2. Permission to ask before draining into water resources.
3. Draining the harmful chemicals is in the groups of general binding rules which have a special drainage permit, must be registered.

In order to ensure the emissions satisfy the water quality standard which the members of EU have to follow the standards are 1) Using best available technology and 2) the emission pollutant water. It has to satisfy the emission standard: however, the non-point sources have to use the best practice.

2.4 The effluent tax charge applied in Foreign countries

2.4.1 Charges Support River Basin Agencies in France

The effluent charge system in France generates revenues that support six French river basin agencies created in the 1960s. These agencies carry out planning and research and provide loans and grants for water and wastewater management projects, but they do not construct facilities or issue regulations.

Effluent charges are set through a complex negotiation process involving a river basin agency's staff, the agency's "basin committee," and a host of government officials. The basin committee includes representatives from various French ministries and from municipalities and other water users. Negotiations in setting the charges account for how much money will be needed to achieve different cleanup targets, since a portion of the charges collected are used by the river basin agency to subsidize wastewater treatment by firms and municipalities. Although the diversity of interests represented in establishing charge levels sometimes slows the decision-making process, it increases the chance of developing a program of action that is fair, implementable and not challenged in court.

The French effluent charge system includes the following parameters: oxidizable material assured by a combination of chemical oxygen demand (BOD), suspended solids (SS), phosphates and toxic materials. For any one year, a base effluent charge for a river is set to yield the total revenues needed by the river basin agency to meet water quality goals for the year. Suppose, for example, the base effluent charge for suspended solids for one year is the equivalent of about $10 per year per kg/day of SS discharged. This charge is multiplied by the pollutant discharge (fee for suspended solids). The pollutant discharge used in calculating the annual fee is based either on periodic measurements (for large/sources) or standard tabulated values per unit of output (for example, 10 gms of SS per kg of finished kraft paper). When tabulated values are used, it is necessary to know the quantity of finished product produced per unit time.

Effluent charges can be raised or lowered, depending on charges in the scope of the action program for a particular river basin. In addition, charges can vary from one zone to another. Thus waste sources in zones with major water quality problems and costly cleanup programs may have to pay relatively high charges. However, those waste dischargers may be eligible for subsidies, grants, and loans that the river basin agency provides using revenues from charges it collects. (Ortolano, 1997).

During the 1970s, the effluent charges used by the basin agencies were much lower than required to motivate dischargers to treat their wastewaters. Why, then did so many polluters implement high levels of treatment during that period? The answer is found by considering a complementary part of French water quality management strategy: effluent standards. French water quality management strategy: effluent standards. Since 1917, the prefects of French "departments" (similar to provinces) have issued permits controlling the discharge of wastewaters. Penalties for the permit system was not implemented effectively. Even through basin agencies do not issue permits, their programs of charges and subsidies have motivated polluters to reduce their wastes in compliance with permit conditions. The use of a two-part strategy economic incentive administered by prefects has led to substantial water quality improvements (Ortolano, 1997).

In France, using many substances as a parameter for calculating the effluent charge such as SS, BOD, COD, N_{tot}, P_{tot}, inhibiting substances, organic matter, soluble salts, fish toxicity, oxidized N, reduced, N, AOX, heavy metals. Effluent charges are calculated according to the following basic equation.

$$EC = f\,(a_i, p.u._i);\ 1 <= i <= n$$

where

EC: Effluent charge for one year.

a: charge rate.

p.u.: pollution units discharged in one year.

n: number of pollutants entering the calculation; all ECS consider more than one pollution parameter.

However, the rate in France differs among the six regional water agencies and also according to the size of the urban area, (Buckland, J. and Zabel, T., 1998).

2.4.2 Netherlands: Experience with how charges Influence Firms

Netherlands in the 1960s. During that period, a law requiring adaptation of a nationwide system of effluent charges was adopted. In the Dutch system, effluent charges are levied on oxidizable materials (as measured, for example, using chemical oxygen demand) and heavy metals, such as mercury and zinc. The Dutch effluent charge scheme was initiated primarily to generate government revenues to subsidize waste management efforts. However, the charge itself has proven to be effective in motivating firms to abate pollution. One reason the Dutch charge scheme has affected behavior is that effluent charges are comparable to the incremental costs of waste reduction for some dischargers.

Soon after the introduction of effluent charges, wastewater releases decreased dramatically in the Netherlands. For example, between 1970 and 1980, the discharge of oxygen-consuming wastes by industry dropped by more than half, even though industrial output expanded significantly over the same period.

Could the falloff in pollution be attributed to the use of effluent charges? Or were there alternative explanations for the cutback?

Several research studies were conducted to determine the influence on polluters of the Dutch effluent charge system. Some studies used statistical methods to identify factors which correlated with sharp decreases in water pollution in Holland during the 1970s. Other investigations relied on survey questionnaires and interviews with government officials and corporate decision makers. While the research studies yielded some differences in details, they were consistent in pointing to effluent charges as a key factor affecting the behavior of polluters. For example, statistical analyses and survey-based research showed effluent charges as being much more significant that the Dutch permit requirements in causing industry to reduce organic pollution. Moreover, subsidies for pollution control, the original motivation for developing the charge system, seemed less important than either discharge permits or effluent charges in encouraging firms to abates pollution.

Results indicate that the Dutch charge system has provided regulators with an influential addition to the previous regulations with an influential addition to the command and control scheme that had been in place, (Ortolano, 1997).

Netherlands, direct and indirect sources have to pay for the effluent charge. The charge rate is determined by the quantity and nature of the waste water and is calculated by the multiplication of the pollution load by the unit tariff, for instance HFL 59 to 138; € 26.8 to 63 in 1995 (average tariff was HFL 82; € 37.2 in 1995). Households and small firms (pollution load below five pollution equivalents) are charged by a fixed amount: average charge for household was HFL 204; € 92.6 (discharging to non-state waters or sewerage) and HFL 127.5; € 57.9 in 1992. The waste water charges are not related to water consumption. Companies of intermediate size are normally charged based on a scheme considering the number of employees, the type of activity, and consumption of water and raw materials; enterprises with emissions above 1000 p.e. are charged according to actual measurements of the quantity and concentration of emissions.

2.4.3 German Experience with Charges

The earliest applications of effluent charges were by river basin agencies in the Ruhr Valley of Germany in the 1920s. During the 1970s, the application of effluent charges was extended to all of what was then the Federal Republic of Germany (FRG or West Germany). An effluent charge law passed in 1976 required the Lander (which corresponded to states in the FRG) to levy charges on effluents released into public waterways. Uniform charge rates were set for the nation as a whole, but implementation was carried out by individual Lander.

Administration of the charge scheme was tied to a discharge permit system. The Lander issued permits to sources of wastewater discharge. Based on the permit system, a polluter is given a right to release specified quantities of wastewater discharge. Based on the permit system, a polluter is given a right to release specified quantities of wastewater, but the concentration of pollutant must be below. Those specified by uniform national discharge standards, or by local discharge standards. (The latter may be set more rigorously than national discharge standards, or by local discharge standards.) A second component of a permit details the data needed to calculate a polluter's waste discharge bill. Using a ratc schedule set a t the federal level, effluent charges are levied on the following parameters: settle able solids, chemical oxygen demand, cadmium, mercury, and toxicity for fish. Details of the computation of total charges are complex, because the basic charge is in units of deutsche marks per "damage unit." The effluent charge law spells out how to convert from quantities of pollutant to damage units (for example, 45.45 kg of chemical oxygen demand corresponds to one damage unit). The same charge per damage unit is applicable to all polluters in all regions of the country.

Based on their analysis of the FRG effluent charge system, Brown and Johnson (1984) argue that to be politically viable and administratively attractive, an effluent charge system should have the following characteristics:

(1) It covers a small number of pollutants.

(2) It is combined with permit system.

(3) The charges begin at some specified level and escalate during a transition period.

(4) The charge levels result from a process involving the participation of interested parties including those benefited and harmed by waste discharges.
(5) Measures and levels of volumes and pollution concentrations are simplified.
(6) Effluent charge revenues are made available for abatement related expenditures.
(7) Hardship clauses are provided to protect discharges or industrial sectors under exceptional circumstance.
(8) Care is taken to demonstrate how the effluent charge program actually can be implemented.

The charge system used in the FRG had features encouraging firms to meet effluent standards. Under the FRG scheme, if applicable wastewater discharge standards were met, a polluter's effluent charge bill would be cut in half. If standards were violated, a polluter lost the opportunity to save 50% of total charges and faced fines and other penalties for violating standards. In addition, revenue from charges were used to subsidize waste reduction activities by both firms and municipalities, and subsidies to offset the cost of waste-reducing changes in production processes. As a result of actions at least partially motivated by the effluent charge program, more than half the waste dischargers in the FRG met effluent standards in 1981, and it one Lander the figure was 90%.

In appraising the influence of the charge scheme on pollution abatement by firm, Brown and Johnson (1984) cited the experience of BASF, a large chemical company in the FRG. The firm made numerous innovative efforts to reduce wastes, even though effluent being much lower than required to induce firms to achieve the nation's water quality goals. Of special note was BASF's development of an intra-firm effluent charge scheme for reducing chemical oxygen demand. The firm computed an internal effluent charge counting price per unit of waste and multiplying it by the total effluent generated b the branch. Brown and Johnson (1984) summarized the results from applying the internal charge scheme over a seven-year period:

The response to the introduction of an internal liability system as internal liability system has been a 20 percent decrease in discharge. Rather than mandate physical decreases the intra-firm charge elicited a "voluntary" decrease in effluent discharge achieved through process change, recycling of solvents, improved pretreatment facilities and replacement of old facilities, (Ortolano,1997).

Brown and Johnson (1984) went on to argue that "Even if the effluent charge is modest, it induces cost saving."

In German, direct discharges into surface waters (rivers, lakes, the sea and groundwater) by industrial and municipal sources are a payer for effluent charge. The charge is calculated by multiplying the number of pollution units by the tariff: DM 60; € 30.5 per pollution unit (1993) DM 70; € 35.5 per pollution unit since 1997. However, the government has another motivate program for polluter to reduce their emission by using tax reducing scheme. Tax reducing is possible under the following conditions:
discharge can get a 75 percent tax relief if they achieve the Technology-based standard (Best available technology - BAT) which is formulated in the law (NRA 1995; Smith 1995:27)

2.4.4 Discharge Fees and Subsidies in China

Using of pollutant discharge fees in China during the early 1980s, a time when China started modifying its economic system to rely more on markets.

The impetus for introducing fees on pollutant discharges came from Chinese environmental man-discharges came from Chinese environmental management experts familiar with effluent charges in Europe. During the late 1970s, these experts argued that China could benefit from a discharge fee program because the fees would enhance productive efficiency and give enterprises incentives to abate pollution. China's 1979 Environmental Protection Law included a system of pollutant discharges fees. Subsequent policy guidance and additional legislation provided details that local environmental protection bureaus (EPBs) needed to implement the system. Although the guidance is for a national charge scheme, EPBs can modify the national system to accommodate local conditions, provided the local system is at least as demanding as the national scheme.

In a typical application of the national pollutant discharge fee system, an enterprise pays fees only if applicable discharge standards are violated. The amount owned by an enterprise violating standards is based on the extent of violation. For example, consider the fee schedule for chemical oxygen demand used in Guangdong Province in southern China. if a firm's wastewater discharge has a COD concentration between one and two times the applicable COD effluent standard, 110 mg/l, the enterprise pays 0.04 Yuan (RMB) per cubic meter (¥/m^3) of discharge. However, if the enterprise's COD exceeds the standard by a factor of ten, the applicable fee is 0.06 ¥/m^3. Guangdong Province uses formulas to calculate unit fees (in ¥/m^3) based on the extent of violation of the standard.

The influence of the Chinese discharge fee system on the behaviors of polluters differs depending on whether the discharges consist of non-hazardous organic wastes or hazardous materials such as heavy metals. First, consider fees on organic wastes (measured using COD). During the 1980s, pollutant discharge fees on organic wastes in China were generally too low to affect polluters. Although many factories cut back their waste discharges, they did so because of pressures unrelated to the fee system. Fees were not influential because operation and maintenance costs for treating organic wastes were often much greater than applicable fees. In such cases, even if the costs of constructing treatment plants at factories had been fully subsidized, fees would still have been ineffective as an incentive to clean up. It was much cheaper for the factories to simply pay fees.

Discharge fees for hazardous material were often relatively high (compared to fees on COD), and they had a greater influence on polluters. For example, consider the release of cadmium, chromium, and other dangerous metals from local EPBs and residents downstream of cleanup from local EPBs and residents downstream of wastewater discharges. In this context, factory managers viewed pollutant discharge fees as one more reason to abate pollution. This outcome is consistent with some experiences in Europe: discharge fees can motivate cleanup even when fees are lower than incremental costs of waste reduction (Ortolano, 1997).

2.4.5 Phillippine

From the research of Indab et al. (2003) the study in terms of cost savings and pollution discharge reductions, the use of effluent charge scheme as a management tool for protecting and maintaining good water quality in Sarangani Bay. The ambient standard set by the Department of Environmental Studies and Natural Resources (DENR) served as a basis for assessing water quality of the Bay. The study assumed that compliance with the ambient standard (Class SB) would bring the level of pollution discharge to Sarangani Bay at a non-damaging level. This standard of maintaining a maximum BOD_5 ambient level of 5 mg/L was then used as the basis for setting the effluent charge level. The ambient requirement was converted in terms of mass through a deterministic water quality assessment model, to determine the allowable pollution discharge to the Bay. Results showed that Sarangani Bay could assimilate as much as 19,134 metric tonnes (t) of BOD_5 annually without exceeding the ambient standard for Class SB. Given the existing annual discharge (6,114 t BOD_5) of the industrial sector, requiring the necessary reduction from this sector alone would mean bringing the level of abatement to 92%. Based on the econometric simulations conducted, Pesos 6 (USD 0.11)/kg BOD_5 effluent charge level is sufficient to realize the needed industrial pollution reduction (i.e. 92%). Achieving the same level of reduction under a pure Command and Control (CAC) scheme, total abatement cost would amount to approximately Pesos 685 million (USD13 million). This implies that achieving the same level of pollution reduction target is approximately Pesos 14 million (USD 264,150) more expensive under the existing CAC scheme than one that complements CAC with effluent charge. The considerations associated with direct regulation also apply to economic instruments. There is still a need to know what the harmful level is; the need for monitoring and enforcement remains and these factors also serve as the main argument that favors economic instruments over a pure CAC scheme. Economic instruments or other instruments will not deliver economic efficiency and achievement of environmental goal if the instruments are not enforced effectively. It is far from attainable under a pure CAC scheme to allocate sufficient manpower and technical resources to enhance enforcement and monitoring to ensure that a 92% industrial pollution reduction will be achieved. If CAC could be complemented with effluent charge scheme, a certain proportion of revenue from pollution charges could be used to cover the implementation cost and/or used for self-construction of environmental protection agencies. In achieving economic efficiency and in effective environmental management, a Pesos 14 million (USD

264,150) abatement cost saving may not be significant compared to the experiences of other countries, but its value is appreciated.

2.4.6 India

The report of Maria (2003) the report tries to summarize the information available about the different costs of water pollution in India. The variety of these costs comes not only from the variety of pollution dealt with (domestic, industrial, agricultural) but also from the method used to calculate these costs. However, the notion of cost is quite complex. Formally, it implies the comparison between two scenarios, and the assessment of the welfare of a group of economic agent in both scenarios. In the case of water pollution, the problem can be represented by a resource which provides environmental services, and economic agents that benefit from these services. Calculating a formal cost of water pollution would imply to model the different equilibrium at stake, and to deduct from these different equilibrium the effect of a difference in the ambient pollution on the aggregated welfare.

To determine these equilibriums, one would need hydrological as well as agronomic, medical and behavioral models that are not available as for now in India.

In practice, many different techniques are applied in order to provide estimates of the economic burden due to water pollution, that only provide partial estimates of a certain kind of cost, that is the cost of a particular aspect of pollution on a certain category of agents.

The goal of a pollution control policy is to get as close as possible to the state that maximizes the aggregated social welfare. Considering the level of pollution, the highest social welfare should be obtained by pollution abatement until the point at which the marginal abatement cost and the marginal environmental damage avoided through this abatement have the same value. Identifying such a point would imply to know precisely the aggregated abatement cost function of the national industry. Therefore, studying the cost of industrial pollution abatement is a critical element in defining an economically and ecologically sound policy for pollution control. There have been several studies carried out by Indian academics during the 90's in order to provide information about the cost of compliance with environmental standards for the Indian Industry.

In a brief paper prepared by IGIDR for the UNDP, general estimates of the cost of pollution abatement the Indian Industry may have to bear are provided. Nevertheless the signification of these figures is difficult to understand since the specification of the hypothetical scenario, especially in terms of ambient pollution standard, are not detailed in the paper. We therefore assume that those figures are referring to a scenario where all polluting industries were complying with the existing pollution standards. It is estimated that Indian industry may have to spend around 2 to 5 % of its capital investment on pollution control. The annual operating costs are expected to be between 15 to 30 per cent of the investment made on the treatment facilities. According to these estimates, the total annual investment needed for water pollution abatement across all the water polluting industries is estimated at R. 1400 crores, which is about 1.17M of the annual turnover of these industries.

This document does not provide any original figure or data. It is a preliminary literature survey of the Indian context regarding water pollution. Although it aims at being as comprehensive and exhaustive as possible, many important elements might be missing, but we hope that reactions from the different partners will enable us to provide a reliable basis for common understanding and fruitful collaboration.

Political will, or financial resources are often quoted as critical element for a sound environmental policy, but information is surely at least as important as the other elements. Information on the status of environmental quality, on the sources of pollution, and the way it affects the different actors. This is the availability of such information, and the way it is being analysed and used in India that they tried to assess.

It appears that the availability of this kind of information has been enhanced by the effort of various institutions during the last fifteen years. The Central Pollution Control Board (CPCB), the Central Ground Water Board (CGWB), the Central Statistical Organization (CSO) and several other institutions now provide nation wide data about water quality, industrial activity, etc.

CHAPTER III
METHODOLOGY

3.1 Study site

As shown in the figure 3-1, the entire study covers 11,763 sq. km. or 7.35 million Rai in 9 provinces which are Bangkok, Ayuthaya, Nonthaburi, Chainart, Uthaithani, Suphanburi, Nakornphathom, and Samutsakorn.

3.1.1 Land use in the Thachin River

From the data collection of the Ministry of Agricultural and Co-operation Thailand, the percentage of land use are (a) rice fields 39.1%, (b) other crops 32.96%, (c) residential/urban areas 8.14%, (d) forest 6.96%, (e) aquaculture 6.09%, (f)orchards 4.31%, (g) water reservoirs 1.1%

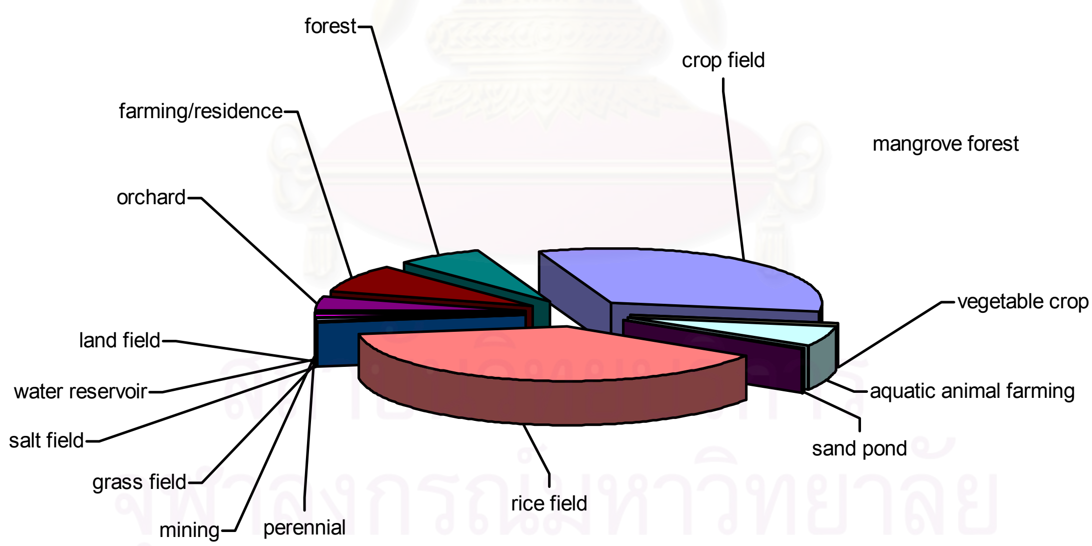

Figure 3-1: Proportion of Land use in Thachin River Basin
Source: PCD (2005a)

3.1.2 Significant pollution-generating sources in Thachin River Basin

3.1.2.1 Pig farm

Agricultural activities such as pig farming are point sources in Thachin River basin. There are 1,065 pig farms which are mostly located between the middle and the lower parts of the Thachin river basin in Nakornpathom and Supanburi provinces.

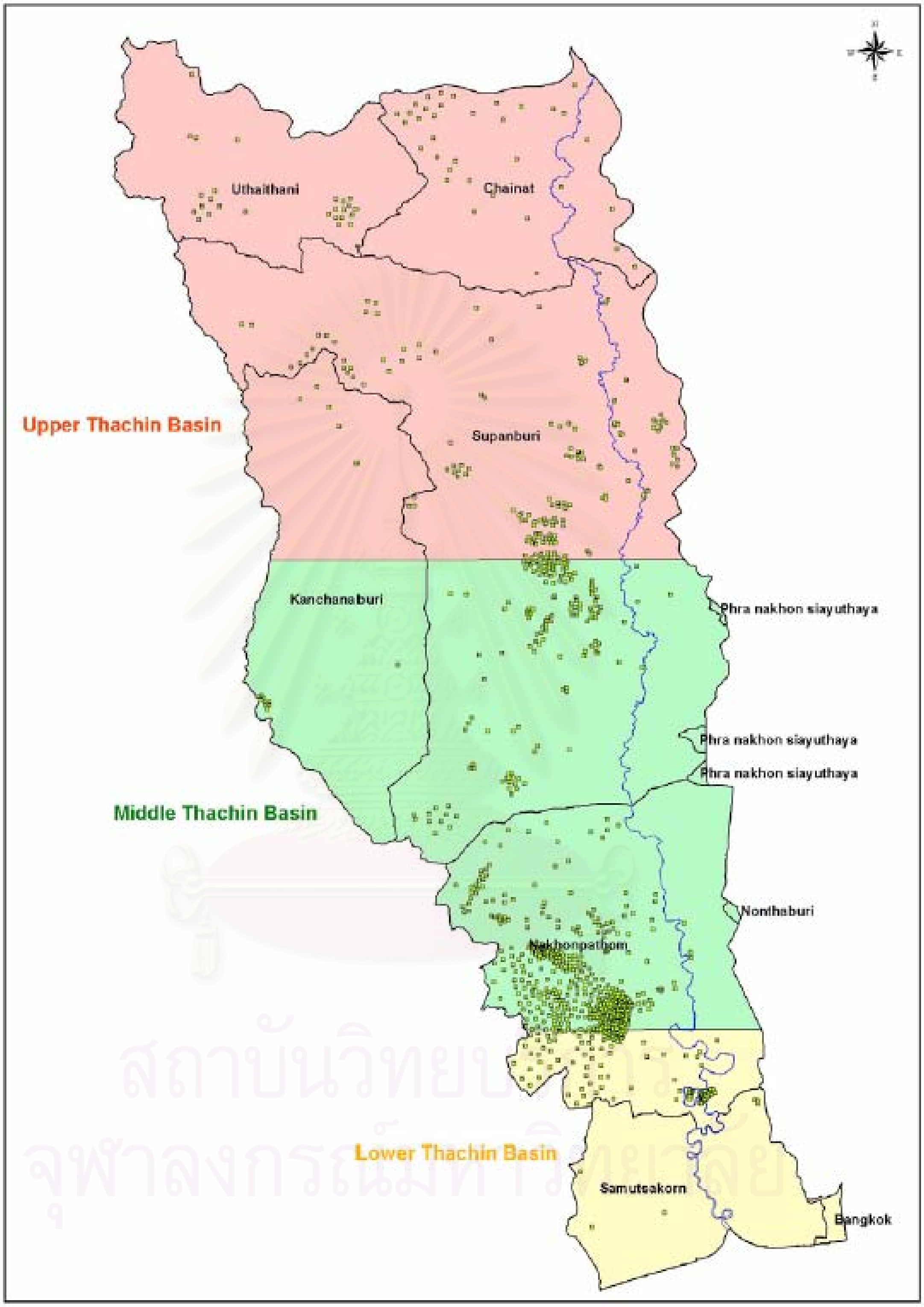

Figure 3-2: Location of pig farms in Thachin River Basin
Source: PCD, (2005a)

3.1.2.2 Urban communities

In the Thachin River basin, there are communities spread along the river especially the lower basin which are densely populated communities and become main point pollution sources. These densely populated communities located in the centre of provinces and districts, create many commercial and services activities which generate large wastewater amounts similar to a city municipality. Moreover, the scattered small communities along Thachin River are often tourist attractions with associated business and services activities to server visitors. The wastewater of these activities are released directly into the river. Thus, small communities along Thachin River have also become main point sources in the area. The large communities situated in the basin are shown in Table 3-1

Table 3-1: Number of large communities situated in Thachin River Basin

Sub-Basin	Province	Number of communities			Total number of communities
		Metropolitan	District municipality	Sub-district municipality	
Upper-Basin	1. Chainat	-	-	3	3
	2. Utaithani	-	-	2	2
	3.1 Supanburi	-	-	10	10
	4.1 Kanjanaburi	-	-	2	2
Middle-Basin	3.2 Supanburi	-	1	9	10
	4.2Kanjanaburi	-	-	1	1
	5. Ayuthaya	-	-	1	1
	6.1 Nakornpathom	1	-	9	10
Lower-Basin	6.2 Nakornpathom	-	-	5	5
	7. Samutsakorn	1	2	4	7
	8. Bangkok	-	-	-	-
	9. Nontaburi	-	-	-	-

Source: PCD, (2005a) refers to Department of Public Works and Town & Country Planning

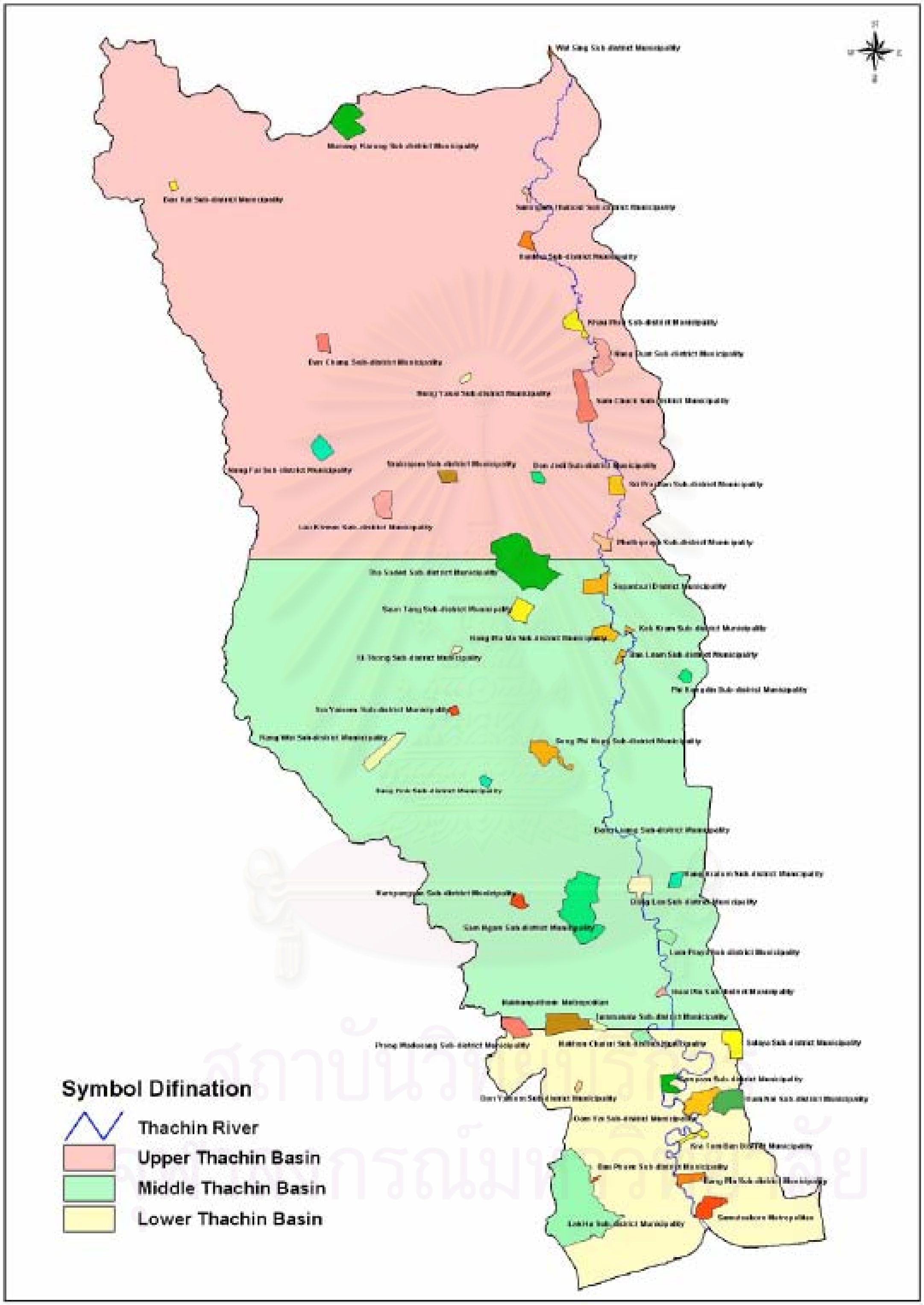

Figure 3-3: Location of large communities in Thachin River Basin
Source: PCD, (2005a)

3.1.2.3 Aqua culture

Aquaculture/fish farming producing prawns and fish and are dispersed in the middle and lower parts of Thachin River basin, especially in Samutsakorn, Supanburi, and Nakornpathom provinces. 75% of the land use of Thachin river basin is for agricultural purposes such as raising livestock, fish farming which have become important pollution sources. From phase I, the total area of aquaculture covers 440,901 Rai and the average BOD loading is 0.23-0.26 kg-BOD/Rai-day. Hence, the Total BOD daily loadings are around 80,362 kg/day.

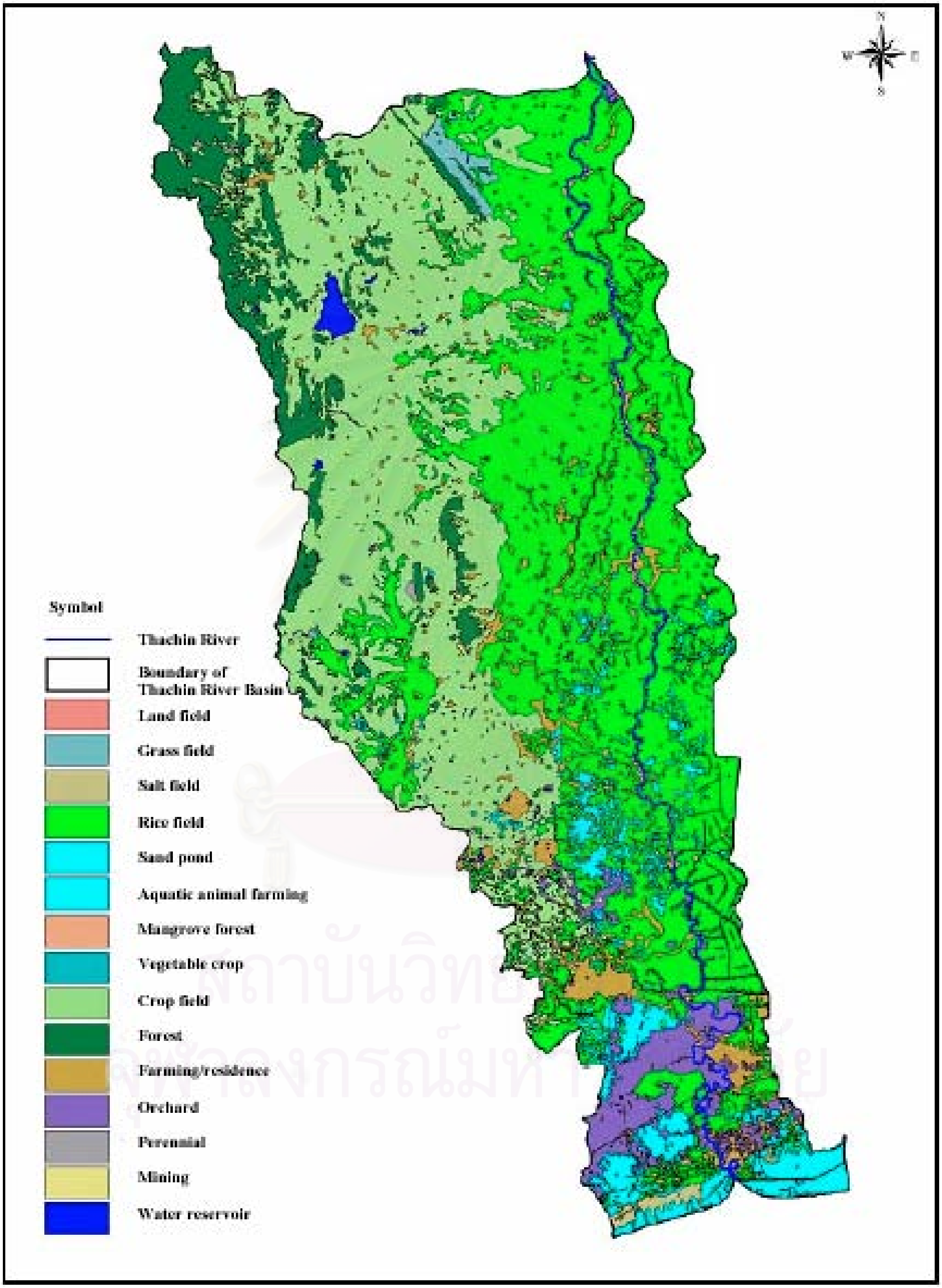

Figure 3-4: Location of Aqua culture in Thachin River Basin
Source: PCD, (2005a)

3.1.2.4 Industry

Factories are the main pollution generators due to the release of polluted water directly into the river. The quantity and types of wastewater from each factory differs depending upon the raw material, products, processing and machinery. However, some factories have no polluted water as no water is involved in the production process. The National Environmental Committee and Industrial Work Department has divided factory types generating pollution water into 34 categories such as daily manufacturing, abattoirs and animal food products, vegetables, processed bakeries, bleaching and dyeing fibers etc., Factories are potential wastewater sources as shown in Table 3-2. However, these factories have wastewater treatment systems which meet the standard requirements before being released into the river.

Along the Thachin river there are many factory types scattered along the river and these establishments are shown in the table below:

Table 3-2: Number and type of factories generating water pollution in Thachin River Basin

No	Types of industry	Industrial activity	Number of factories generating water pollution	Level of water pollution severity
1	4(1) 4(2) 4(3)	Slaughtering The preservation of meat by toast, smoke-dried, pickled, sun-dried and sharply freezing method Processed food products from animal meat, fat, hide and grease or born extract	6 5	2 2
2	5(5) 5(6)	Processed cheese and butter Processed yogurt	1 2	2 2
3	6(1) 6(2) 6(3) 6(5)	Processed aquatic animal food and canning The preservation of aquatic animal by toast, smoke-dried, pickled, sun-dried and sharply freezing method Processed food product from aquatic animal and hide or fat of aquatic animal Sliced, boiled, steamed, fired, and grinded (fish) aquatic animal	19 56 31 30	2 2 2 2
4	7(1) 7(4)	The extraction of vegetable and animal oils and fats Processed pure vegetable and animals oils and fats	14 2	2 1
5	8(1) 8(2)	Canning of fruit and vegetables Preserving of fruit and vegetables	42 34	2 2
6	9(2) 9(4)	Processed starch Grain mill products manufacturing	10 17	2 1
7	10(1) 10(2) 10(3)	Processed bakeries Processed biscuits Baked and steamed products manufacturing	33 26 51	1 1 2
8	11(2) 11(6)	Processed sugar refineries Processed glucose, dextrose, fructose and similarly other products	3 1	2 1
9	12(9) 12(11)	Processed chewing gum Processed ice-cream	4 13	1 1
10	13(2) 13(3)	Processed additive Processed powder-yeast	44 3	2 1
11	15(1) 15(2)	Prepared animal feeds Grinded vegetable, grain, meat, bone and shellfish for animal feeds	64 46	1 1
12	16	Manufacture of distrilling rectifying and blending spirits	8	2
13	20(1) 20(2)	Processed drinking water Processed non-alcoholic drinks	16 14	1 2

Table 3-2: (continued)

No	Types of industry	Industrial activity	Number of factories generating water pollution	Level of water pollution severity
14	22(1) 22(2) 22(3) 22(4)	Carbonize incubation, bleaching and dyeing fibers Spinning of cotton Textile finishing Textile printing	72 160 103 71	1 2 2 2
15	24	Knitting mills	185	2
16	30	Manufacture of fur dressing and dyeing	2	2
17	38(2)	Processed paper or fiberboard	17	2
18	42(1)	Processed chemicals	64	2
19	43(1)	Processed fertilizer and pesticides	15	2
20	44	Synthetic resin rubber, plastic or synthetic fiber manufacturing	2	1
21	45(1) 45(2) 45(3)	Processed paints Processed varnish Processed lacquer	35 16 10	2 2 2
22	46(1) 46(2) 46(3)	Objects which are accepted in medicine text book manufacturing Objects which cure, relieve and protect disease for human or animal manufacturing Objects which follow 46(1) and 46(2) except foods, sport equipment, cosmetics and curing instrument manufacturing	8 4 1	1 1 1
23	47(1) 47(3)	Processed soap and cleaning preparations Processed cosmetics	3 8	1 1
24	48(1) 48(3) 48(6) 48(9) 48(10)	Processed bees wax Processed water proof products, emulsifier, wetting agents, sizes, cements, (not dental cements) Ink or carbon black manufacturing Processed essential oil Processed indigo and bleaching powder	3 19 9 2 1	1 1 1 1 1
25	50(4)	Processed miscellaneous petroleum	10	1
26	52(2) 52(3) 52(4)	Sliced cutting and mixed rubber sheets Smoked rubber, crepe rubber, sticky rubber and liquid rubber manufacturing Processed natural rubber product or synthetic rubber	14 1 71	2 2 2

Table 3-2: (continued)

No	Types of industry	Industrial activity	Number of factories generating water pollution	Level of water pollution severity
27	54	Grass and fiberglass manufacturing	12	1
28	55	Manufacture of tile, pottery or ceramic	63	1
29	59	Smelt, melt, mold, press out, haul or produce iron or primary steel (Iron and steel basic)	109	2
30	60	Smelt, mix, purify, melt and mold (Non-ferrous metal basic)	35	2
31	71	Manufacture of electrical industrial machinery and apparatus	28	2
32	92	Manufacture of frozen	96	2
33	98	Laundries, laundry services and cleaning and dyeing plant	20	1
34	101	Central waste treatment plant	18	1
Total number of factories			1,906	-

Source: PCD, (2005a) refers to Classification of industry which generate environmental problem, office of National Environment Board and Department of Industrial Works

Table 3-3: Number of factories generating water pollution for each province in the area of Thachin River Basin

Province	Factories (unit)	Percentage
Bangkok	125	6.56
Kanjanaburi	8	0.42
Chainat	3	0.16
Nakornpathom	578	30.32
Nontaburi	3	0.16
Samutsakorn	1,087	57.03
Supanburi	99	5.19
Utaithani	3	0.16
Total	**1,906**	**100**

Source: PCD, (2005a) refers to Database of factories, Department of Industrial works (DIW)

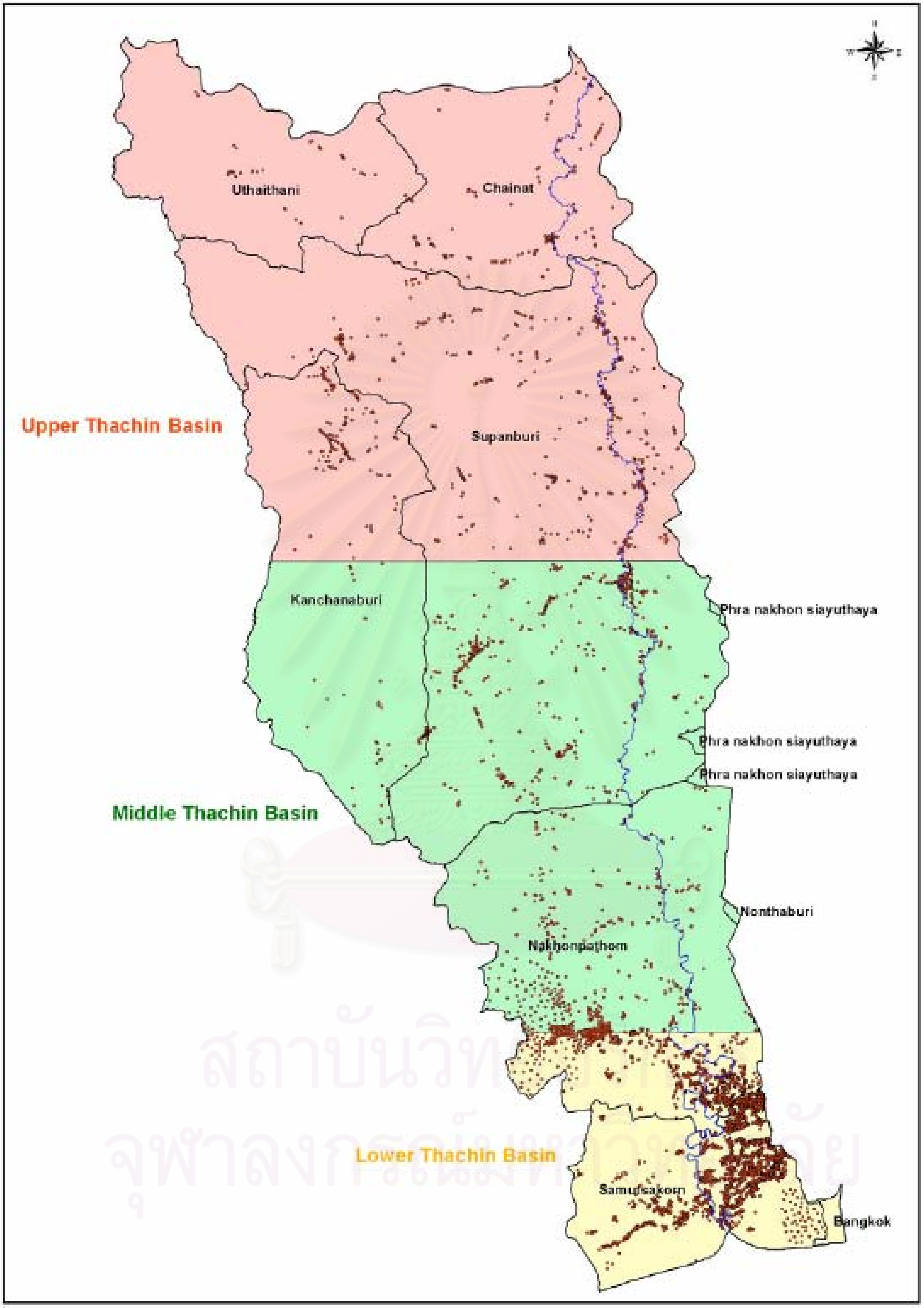

Figure 3-5: Locations of factories generating water pollution in Thachin River Basin
Source: PCD, (2005a)

In the entire Thachin river basin, there are many activities situated along the river, however these actual wastewater discharge activities are monitored and data collected by PCD. The other activities are ignored. Due to the inefficiency in maintaining databases and their randomly distributed nature, the researcher used principally the database from PCD and as a source of information in this research.

Table 3-4: Percentage of pollution from any sources in any sub basin and target of emission reduction

No	Sub basin	Reduction	Pig Farm	Aquaculture	Urban Community	Industry
1	**LI**	50.00%	12.49%	42.43%	43.83%	1.25%
2	**RF**	85.00%	67.27%	17.73%	14.38%	0.62%
3	**LJ**	55.00%	0.00%	97.30%	2.69%	0.01%
4	**LK**	55.00%	0.00%	99.00%	1.00%	0.00%
5	**LL**	55.00%	0.00%	99.49%	0.51%	0.00%
6	**LM**	70.00%	0.00%	100.00%	0.00%	0.00%
7	**RFm**	70.00%	14.11%	81.08%	3.21%	1.60%
8	**LP**	60.00%	11.20%	75.15%	7.50%	6.15%
9	**RG**	60.00%	37.63%	58.16%	0.64%	3.57%
10	**LQ**	95.00%	40.19%	34.72%	24.82%	0.27%
11	**RH**	95.00%	53.59%	3.96%	13.92%	28.53%
12	**RI**	30.00%	13.34%	67.99%	5.16%	13.52%
13	**LS**	25.00%	16.16%	18.13%	21.38%	44.32%
14	**RJ**	25.00%	3.85%	74.51%	3.90%	17.74%
15	**RK**	25.00%	0.25%	96.57%	2.87%	0.32%
16	**LT**	25.00%	0.00%	0.73%	10.00%	89.27%
17	**LU**	25.00%	0.00%	43.81%	22.67%	33.52%
18	**RL**	25.00%	0.03%	77.59%	2.13%	20.26%

Source: PCD, (2005a)

As the tables 3-4 show each sub basin has its own reduction target in order to meet the water quality standards. Each sub-basin has many activities which can be divided into 4 groups. Each group indicates the percentage of water pollution emissions.

3.2 Methodology

3.2.1 Phase I: Database collection

The Thachin river basin covers an extensive area passing through 9 provinces. Therefore to complete the data collection for each parameter, the researcher sought data from various sources such as Pollution Control Department (Ministry of Natural Resources and Environment), Department of Industrial Works and Office of Industrial Economic (Ministry of Industry), Office of the National Economic and Social Development Board, The Department of Local Administration (Ministry of Interior), Asian Institute of Technology, CMS engineering company. Gathering and adjusting of data needed 2 years.

In the first phase, a detailed explanation on how to gather the data is given below:-
The data can be divided into 2 groups, (a) the Environmental Aspects and (b) the Economic Aspects.

3.2.1.1 Environmental Data

Most of this environmental data came from PCD reports which also incorporated AIT and CMS engineering data. The primary data need for the study is processed with the 3 following steps:-

a) Current situation of BOD loading in Thachin River,

b) Total Maximum Daily Loading by using BOD peak reduction base

c) Emission reduction targets.

Methodology used in these steps consists of the following :

1. Establish a GIS database of primary water-pollution-generating sources in Thachin river basin and basin data.
2. Estimate the BOD daily loading from effluent discharges from each source and source type in each sub-basin area.
3. Estimate the current carrying capacity of Thachin river for BOD in effluent discharge, by assuming that some BOD degradation has occurred while the water flows through canals before reaching Thachin river.
4. Estimate the Total Maximum Daily Loading (TMDL) for BOD without exceeding the water classification standard.

The implementing procedure in each step is briefly described as follows,

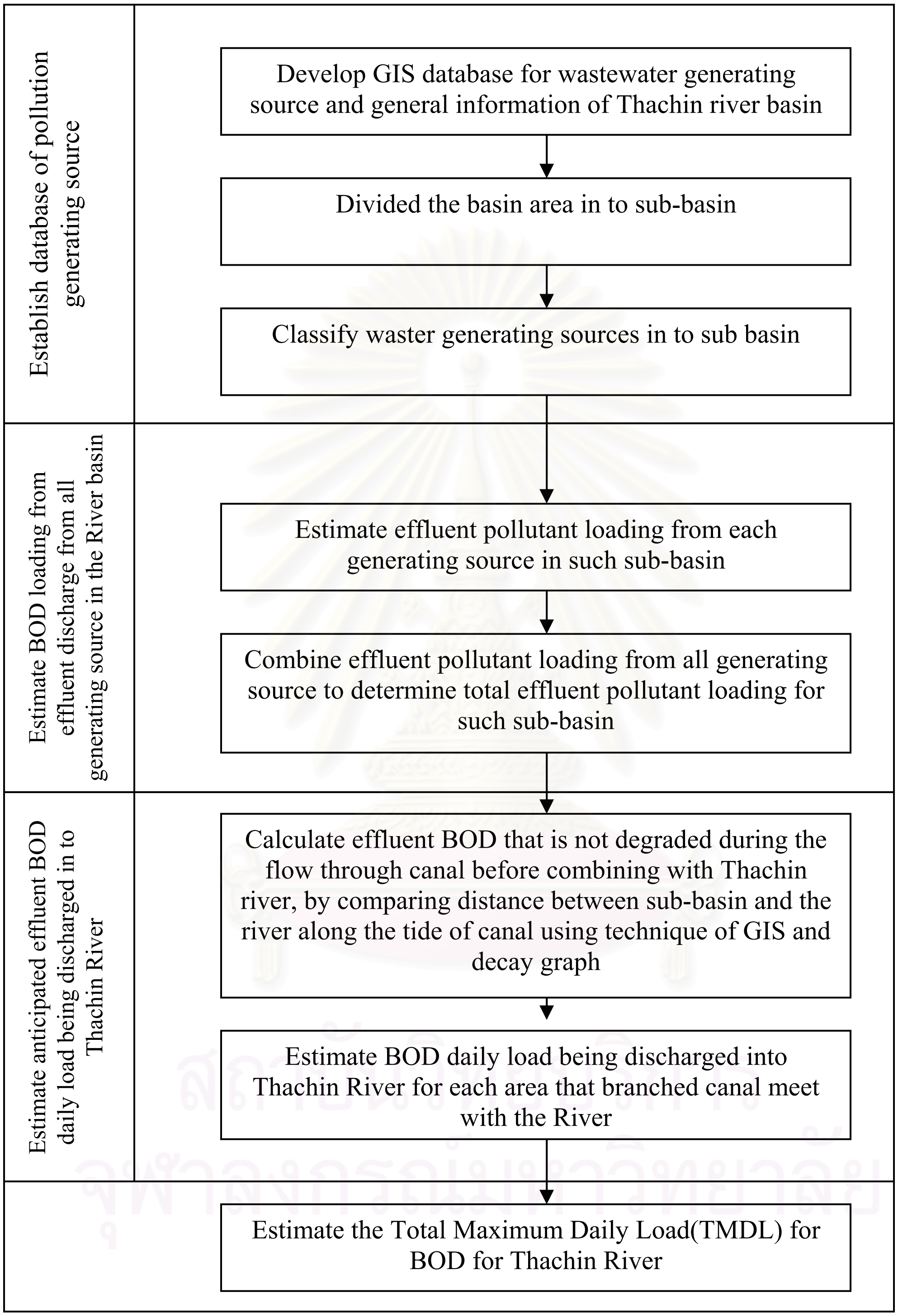

Figure 3-6: Work diagram of Determination of Industrial effluent standard research

Source: PCD (2005a).

From the report of determination of industrial effluent standards: Revision of Industrial effluent standards of PCD, the Thachin river basin into 33 sub-basins as show in the figure 3-7.

a) Current situation of BOD loading in Thachin River.

The result of the current BOD loading and the calculated results of significant main points and non-point sources in each sub-basin are shown in the table 3-5. After obtaining BOD results from each pollution source, the simulated computer river models are shown in figure 3-9.

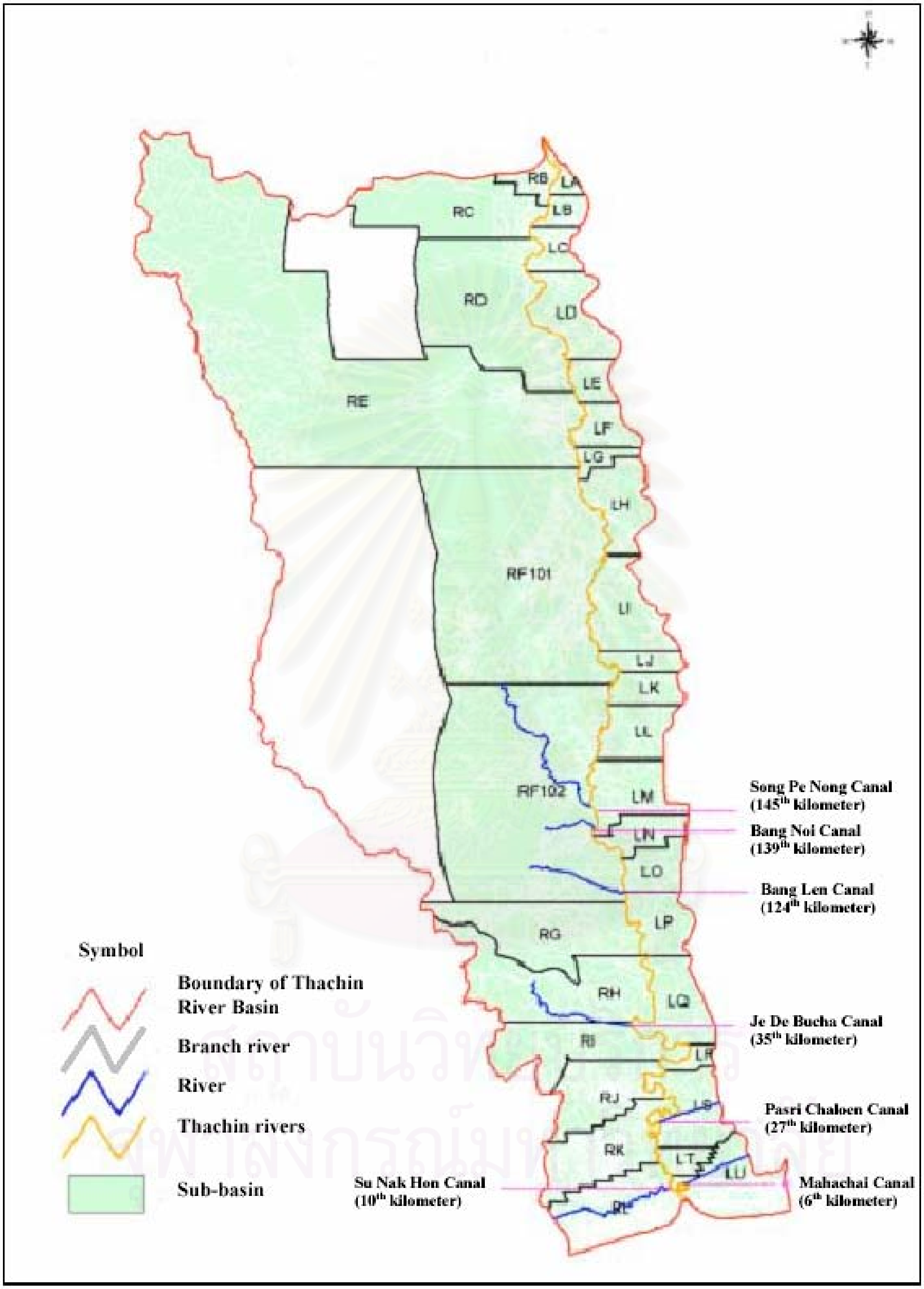

Figure 3-7: Sub-basins which has potential to cause water quality deterioration
Source: PCD (2005a).

Table 3-5(a): Results of daily BOD loading estimation of effluent discharged from 33 sub-basins to Thachin River

Sub-Basin Code	No of GRID	Point Source														
		Dry Season without Rain					Dry Season with Rain					Rainy Season				
		Pig Farm	Aquaculture	Urban Community	Industry	Sub-Total	Pig Farm	Aquaculture	Urban Community	Industry	Sub-Total	Pig Farm	Aquaculture	Urban Community	Industry	Sub-Total
n/a	167	866.9	421.5	64	14.4	1366.8	1332.3	648.6	101.1	22.9	2104.9	1854.4	910.7	142.8	32.1	2940.0
LA	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LB	7	1.7	0.0	0.0	0.0	1.7	1.8	0.0	0.0	0.0	1.8	1.8	0.0	0.0	0.0	1.8
LC	11	0.6	0.0	0.0	0.0	0.6	0.6	0.0	0.0	0.0	0.6	0.7	0.0	0.0	0.0	0.7
LD	35	21.1	16.9	0.0	20.6	58.6	23.3	18.7	0.0	22.8	64.8	25.1	20.1	0.0	24.5	69.8
LE	14	2.7	45.9	2.9	2.5	54.0	3.0	50.7	3.2	2.7	59.7	3.3	54.6	3.4	3.0	64.3
LF	15	15.0	82.4	53.0	6.6	157.0	16.1	88.5	56.9	7.1	168.6	17.0	93.3	60.0	7.5	177.7
LG	9	37.9	0.0	28.7	0.4	66.9	41.3	0.0	31.2	0.4	72.9	44.0	0.0	33.3	0.5	77.7
LH	32	72.0	31.4	14.1	2.4	120.0	79.6	34.7	15.6	2.6	132.6	85.7	37.4	16.8	2.9	142.7
LI	40	83.6	284.0	293.4	8.3	669.3	95.0	322.9	333.5	9.5	760.9	104.5	355.1	366.9	10.4	836.9
LJ	8	0.0	686.6	19.0	0.1	705.6	0.0	747.9	20.6	0.1	768.6	0.0	796.9	22.0	0.1	819.0
LK	14	0.0	1,114.4	11.3	0.0	1125.7	0.0	1213.9	12.3	0.0	1226.2	0.0	1293.5	13.1	0.0	1306.6
LL	27	0.0	1,799.9	9.2	0.0	1809.0	0.0	1960.6	10.0	0.0	1970.5	0.0	2089.0	10.6	0.0	2099.7
LM	33	0.0	3,050.8	0.0	0.1	3050.9	0.0	3419.2	0.0	0.2	3419.4	0.0	3721.2	0.0	0.2	3721.4
LN	13	0.0	1,436.8	0.0	0.9	1437.8	0.0	1565.1	0.0	1.0	1566.1	0.0	1667.7	0.0	1.1	1668.7
LO	20	0.0	928.4	37.9	0.0	966.4	0.0	1011.3	41.3	0.0	1052.6	0.0	1077.6	44.0	0.0	1121.6
LP	28	63.7	427.4	42.7	35.0	568.7	68.4	458.9	45.8	37.6	610.7	72.1	483.9	48.3	39.6	643.9
LQ	51	143.7	124.1	88.8	1.0	357.6	154.3	133.3	95.3	1.0	384.0	162.7	140.5	100.5	1.1	404.8
LR	22	0.0	0.0	11.9	822.6	834.5	0.0	0.0	12.2	846.4	858.6	0.0	0.0	12.5	864.5	876.9
LS	125	1,579.7	1,772.8	2,090.4	4,332.8	9775.8	1721.5	2071.9	2318.9	4767.9	10880.3	1835.0	2330.7	2507.4	5122.6	11795.7
LT	28	0.0	21.7	297.7	2,657.6	2977.0	0.0	23.0	315.1	2813.5	3151.7	0.0	24.0	328.8	2935.2	3287.9
LU	188	0.0	2,544.6	1,316.50	1,946.8	5807.9	0.0	2765.6	1374.0	2051.4	6191.1	0.0	2943.3	1418.3	2133.3	6494.9
RA	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RB	10	33.2	0.0	0.0	0.0	33.2	36.2	0.0	0.0	0.0	36.2	38.6	0.0	0.0	0.0	38.6
RC	57	148.2	0.0	11.9	0.0	160.1	197.1	0.0	15.8	0.0	212.9	243.5	0.0	19.6	0.0	263.1
RD	124	102.3	0.0	167.1	1.4	270.8	125.0	0.0	173.5	1.4	299.9	145.3	0.0	178.5	1.4	325.3
RE	195	229.4	6.4	104.1	101.0	440.8	338.6	12.1	151.9	162.7	665.2	482.4	19.4	218.7	233.2	953.7
RF	216	4,592.2	1,210.4	981.7	42.2	6826.6	5400.6	1321.7	1074.6	55.4	7852.4	6106.5	1413.4	1157.1	68.4	8745.3
RFm	210	1,639.5	9,421.1	372.7	186.5	11619.8	2050.6	10523.7	422.2	216.8	13213.3	2512.4	11443.5	464.6	244.2	14664.6
RG	61	3,147.6	4,865.7	53.7	298.6	8365.6	4075.7	5498.9	67.9	349.9	9992.4	4985.0	6043.0	81.2	394.2	11503.4
RH	369	6,210.5	459.0	1,613.30	3,307.1	11589.9	7735.3	579.2	2019.1	3818.4	14152.0	9163.0	694.0	2388.3	4277.7	16523.0
RI	231	1,416.9	7,223.2	548.1	1,436.0	10624.2	1768.9	8307.4	654.3	1592.1	12322.6	2091.3	9243.3	749.3	1734.5	13818.4
RJ	177	222.4	4,304.1	225.4	1,024.9	5776.8	225.7	5091.6	243.8	1094.1	6655.2	228.2	5772.5	259.8	1151.7	7412.3
RK	210	20.4	7,886.4	234.0	26.0	8166.7	26.5	8868.3	292.2	27.9	9214.8	32.1	9713.0	344.8	29.5	10119.5
RL	213	3.7	11,132.8	305.3	2,906.2	14347.9	4.1	13156.4	330.9	3165.4	16656.8	4.4	14949.8	353.6	3380.9	18688.6
Total	2,967	20,655	61,299	8,999	19,182	110,134	25,521	69,894	10,233	21,071	126,720	30,239	77,331	11,344	22,694	141,608

Source: PCD (2005a).

Table 3-5(b): Results of daily BOD loading estimation of effluent discharged from 33 sub-basins to Thachin River (non-point sources)

Sub-Basin Code	No of GRID	Non-Point Source							
		Dry Season with Rain				Rainy Season			
		Rice Field	Rural Community	Vegetable/Fruit	Sub-Total	Rice Field	Rural Community	Vegetable/Fruit	Sub-Total
n/a	167	463.0	134.8	1214.5	1812.2	684.0	533.6	4431.0	5648.7
LA	7	7.2	3.3	1.7	12.2	66.6	32.5	16.3	115.5
LB	7	7.8	4.2	0.0	12.0	85.7	45.5	0.0	131.2
LC	11	19.8	5.5	0.0	25.3	189.3	50.2	0.0	239.5
LD	35	65.0	15.3	0.0	80.3	585.4	134.3	0.0	719.6
LE	14	38.2	3.6	0.0	41.8	246.9	23.3	0.0	270.2
LF	15	40.1	9.9	0.0	50.0	247.1	60.8	0.0	307.8
LG	9	23.6	13.0	0.0	36.6	143.4	79.1	0.0	222.5
LH	32	47.3	13.9	0.0	61.2	339.6	99.4	0.0	439.1
LI	40	354.0	106.8	0.1	460.9	738.7	303.0	0.1	1041.8
LJ	8	24.3	5.7	0.0	30.0	133.5	31.4	0.0	165.0
LK	14	35.4	5.7	0.0	41.0	194.4	31.3	0.0	225.7
LL	27	76.0	5.8	0.2	82.0	429.8	32.8	1.2	463.8
LM	33	109.3	11.0	0.0	120.3	651.1	62.9	0.0	714.0
LN	13	67.5	6.2	0.2	73.9	353.4	31.8	1.0	386.1
LO	20	75.8	16.5	0.0	92.2	387.8	84.3	0.0	472.0
LP	28	112.7	15.8	8.9	137.3	570.9	79.9	44.8	695.6
LQ	51	119.4	19.2	22.5	161.0	731.7	158.6	161.2	1051.5
LR	22	11.3	11.9	1.2	24.3	114.9	121.5	12.2	248.6
LS	125	44.2	84.0	16.9	145.0	311.2	658.9	127.3	1097.4
LT	28	6.8	30.9	17.1	54.8	44.0	201.3	111.4	356.7
LU	188	17.2	65.6	8.2	90.9	118.8	442.6	56.1	617.5
RA	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RB	10	41.7	6.6	0.0	48.3	225.1	35.7	0.0	260.8
RC	57	104.1	6.5	43.6	154.3	809.4	50.5	300.3	1160.2
RD	124	193.6	29.2	38.1	260.9	1561.6	224.7	360.9	2147.2
RE	195	209.7	70.7	390.4	670.8	1610.8	580.5	3427.8	5619.2
RF	216	1352.5	308.7	67.5	1728.7	4566.0	1032.7	473.1	6071.8
RFm	210	539.5	167.4	114.0	820.9	3106.6	1065.6	379.9	4552.1
RG	61	106.6	34.2	58.9	199.7	681.4	251.5	476.4	1409.2
RH	369	112.7	98.9	37.2	248.8	1075.0	1023.8	419.5	2518.3
RI	231	70.0	51.6	29.5	151.1	641.5	444.4	252.7	1338.6
RJ	177	9.2	9.9	51.4	70.5	117.5	101.4	516.7	735.6
RK	210	17.2	4.9	23.8	45.9	155.8	59.6	369.5	584.9
RL	213	47.2	60.1	9.0	116.3	318.5	416.6	71.5	806.6
Total	2,967	4,570	1,437	2,155	8,162	22,238	8,586	12,011	42,834

Source: PCD (2005a).

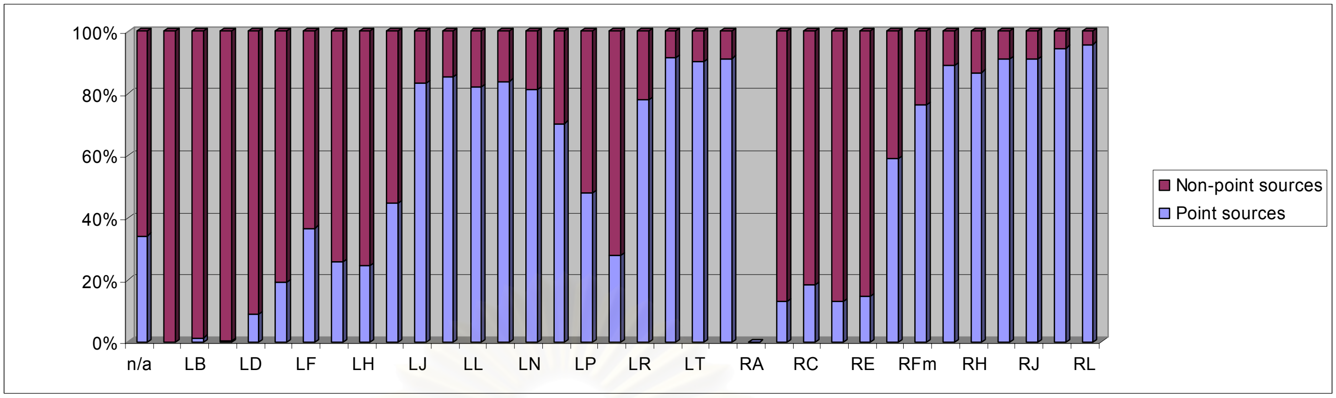

Figure 3-8: Proportion of Point sources and Non-point sources effluent discharged from 33 sub-basins to Thachin River
Source: Modified from PCD (2005a).

In Thachin River, there are Point sources and Non-point sources. The tables of effluent loading are shown in the table 3-5(a) and 3-5(b) and the proportion of point sources and non-point sources are shown in the figure 3-8. Within the scope of study, effluent tax charges can only be applied from point sources. Thus, non-point sources described in the recommendation topic clarifies this further.

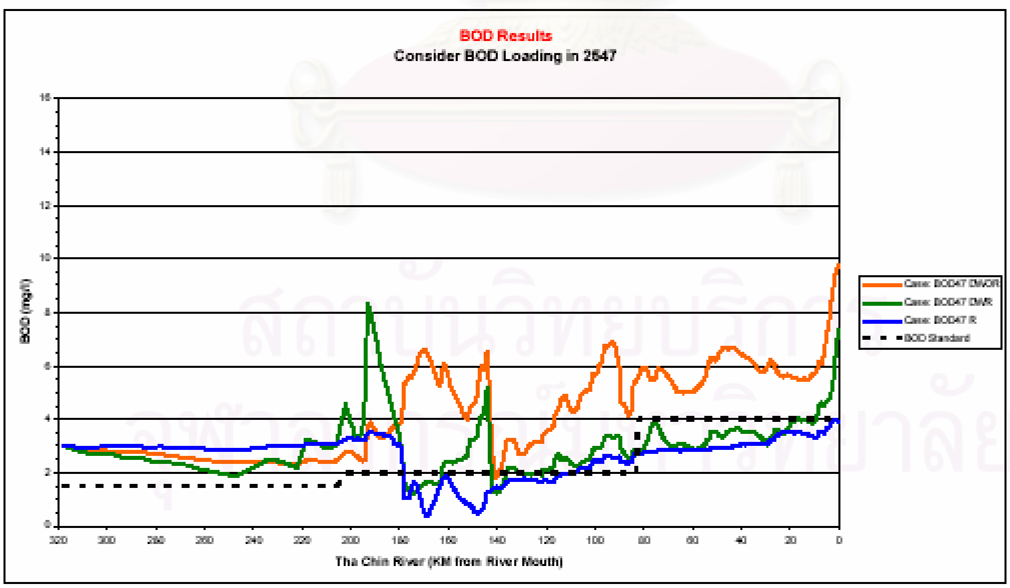

Figure 3-9: Prediction of current water quality in Thachin River using BOD loading from each sub-basin in 2004.
Source: PCD (2005a).

After gathering the PCD data we could identify the types of main point sources which needed to be controlled. The parameters are:-

- point sources distances to the river,
- BOD loading at each source in each sub-basin,
- the volume of waste water treatment (F),
- Concentration in influent stream (I),
- the volume of waste water generated when produced at 'q' units at each main point source (Alpha),
- BOD loading when produced at 'q' units of each main point source (Beta)

b) Total Maximum Daily Loading by using BOD peak reduction basis

The TMDL or Total Maximum Daily Load is a calculation of the maximum amount of pollutant that a waterbody can receive and still meet water quality standards and an allocation of that amount to the pollutant's sources.

Water quality standards are set by states, territories, and tribes. They identify the uses for each waterbody, for example, drinking water supply, contact recreation (swimming), and aquatic life support (fishing), and the scientific criteria to support that use.

A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure that the waterbody can be used for the purposes the State has designated. The calculation must also account seasonal variation in water quality (U.S.EPA., 2007).

The BOD reduction basis is used to consider a specific point or distance at the range of high BOD value. By considering a BOD peak together with BOD details at each point for the main activity producing BOD, the criteria will be set up in order to reduce the BOD until it meets the standard (PCD, 2005a).

After finishing topic a) we can use the data from a) and continue on to part b) and c). In arriving at TMDLs by reducing the pollutants at the particular area that caused BOD peaks.

The BOD peak reduction basis is concerned only by the peak of BOD in the current situation of Thachin river. All BOD peaks in Thachin River basin have 9 points and are shown in tables 3-6.

Table 3-6: High BOD value in all 9 point of Thachin River

No	Km.	BOD value of Thachin River in present (mg/l)	Water Pollution-generated sub-basin	BOD loading form pollution-generating sources that flowed to Thachin River (kg/day)
1	180 – 200	8.0	LI	1,200
			RF	9,600
2	160 – 180	6.5	LJ	700
			LK	7,100
			LL	1,800
3	140-160	6.5	LM	3,000
			RFm	12,000
4	110 – 120	4.8	LP	570
			RG	8,400
5	90 – 100	6.7	LQ	360
			RH	12,000
6	70 – 90	6.0	RI	11,000
7	40 – 50	6.5	LS	9,800
			RJ	5,800
8	20 – 40	6.2	RK	8,200
9	0 – 20	7.0	LT	3,000
			LU	5,800
			RL	14,500

Source: PCD (2005a).

The reason for the increasing BOD is the affect of 18 sub-basins from 33 sub-basins as show in Table 3-6. These sub-basins have high BODs especially between the central and lower sections of the river. 18 out of 33 sub-basins discharged a large volume of BOD which was 90% of BOD from the whole sub-basin. The details are shown in Table 3-7.

Table 3-7: BOD load from 18 sub-basins which generate BOD peak in Thachin River

Season	BOD loading flowed to Thachin River			
	18 sub-basins which generate BOD peak		15 sub-basins which not generate BOD peak	
	BOD loading (kg/day)	Percentage of total BOD loading in Thachin	BOD loading (kg/day)	Percentage of total BOD loading in Thachin
Dry Season without Rain	104,165	96	4,602	4
Dry Season with Rain	124,130	95	6,847	5
Rainy Season	157,338	89	18,625	11

Source: PCD (2005a).

In arriving at the TMDL, the BOD has to be reduced from the starting point through to the end of the river. Starting at areas LI and RF basins, the water quality improved in the range of 180-200 km until it satisfied the water quality standard. Then the reduction of the BOD process would continue to the second group (LJ, LK and LL) at the range of 160-180 km through to the end of the river (LT, LU and RL) that has a higher BOD.

c) *Target of emission reduction*

Target of emission reduction could be found by using the volume of BOD loading of the current situation in each sub-basin and deducting the Total Maximum Daily BOD loading (TMDL), where the results of reduction emissions are shown in Table 3-8 and the water quality are shown in Figure 3-10.

Table 3-8: Allowable BOD discharging load from each sub-basin maintaining water quality in Thachin River to meet standard criteria

No	Km.	Sub-basins have pollution-generating sources	BOD loading from pollution-generating sources that flowed to Thachin River	Allowable BOD discharging load to Thachin River from each sub-basin (% of BOD load at present)	Target of emission reduction
1	180 – 200	LI	1,200	50%	50%
		RF	9,600	15%	85%
2	160 – 180	LJ	700	45%	55%
		LK	7,100		
		LL	1,800		
3	140-160	LM	3,000	30%	70%
		RFm	12,000		
4	110 – 120	LP	570	40%	60%
		RG	8,400	40%	60%
5	90 – 100	LQ	360	5%	95%
		RH	12,000	5%	95%
6	70 – 90	RI	11,000	70%	30%
7	40 – 50	LS	9,800	75%	25%
		RJ	5,800	75%	25%
8	20 – 40	RK	8,200	75%	25%
9	0 – 20	LT	3,000	75%	75%
		LU	5,800		
		RL	14,500		

Source: PCD (2005a).

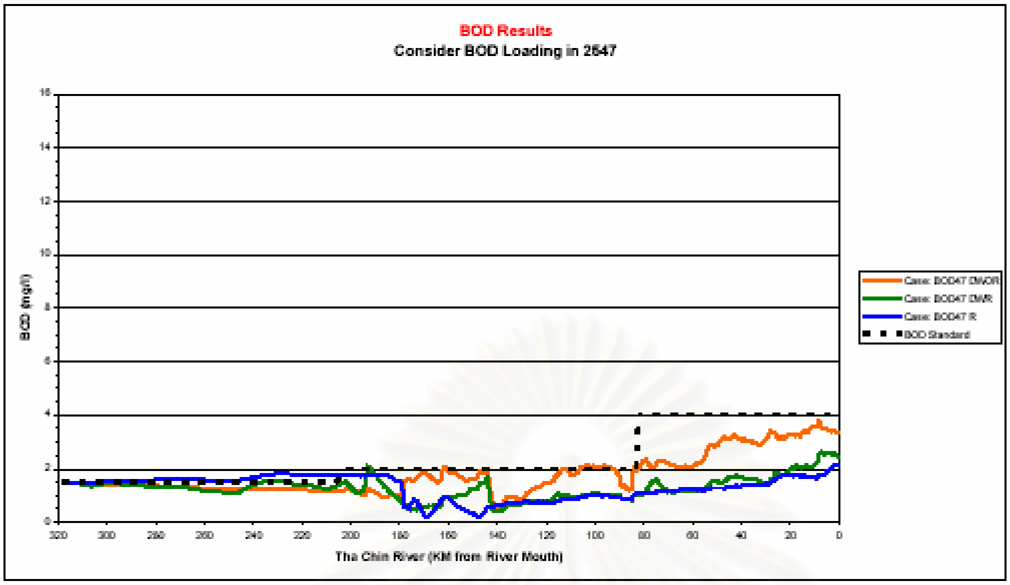

Figure 3-10: Calculated results of BOD values after reducing BOD loading at particular areas that led to a BOD peak
Source: PCD (2005a).

Controlling BOD that does not exceed the PCD standard is shown in Table 3-8 and Figure 3-10. After defining the allowable BOD loading and the reduction percentage, use continues with the information for phase II and phase III.

3.2.1.2 Economic data of significant pollution

There are four significant point sources in this paper. This section explains how to gather the data relating to costs and estimating economics.

First, obtain the current BOD results, and compare the total maximum daily loading with the water classification standard. Then the BOD has to be reduced to meet TMDLs., this reduction of volume is called the 'emission reduction target'.

The emission reduction target will be used with the marginal abatement cost curve in order to find the tax variation in any sub-basin.

The data in 3.2.1.1 and 3.2.1.2 are needed to calculate MAC function coefficients, based on :

- the Cost of Abatement (C),
- volume of waste water (F)
- pollution concentration in influent (I)
- effluent (E). More details are explained in data analysis of Phase II.

a) Pig farm

Data from the PCD report “Development and Technology of Wastewater Management where parameters comprise the cost of abatement in any type of pig farm i.e., price of 100 kg of pig unit and variable costs.

Table 3-9: Transaction cost of pig farm waste water treatment in each size

Detail	Small Biogas (Digester+FP[b]+MP[c])	Medium Biogas (Carmatec digester+FP[b]+MP[c])	Large Biogas (UASB[a]+FP[a]+MP[c])
Volume of wastewater (cubic-meter/day)	10.00	30.00	50.00
Area of wastewater treatment system (square meter)	100.00	1,750.00	2,000.00
Land price (Baht)	-	-	-
Construction cost (Baht)			
Civil structure (a)	54,000.00	367,000.00	760,000.00
Machinery equipment (b)	-	-	-
Electricity system and piping (c)	2,000.00	10,000.00	60,000.00
Preliminary cost	56,000.00	377,000.00	820,000.00
Safety factor 20%	11,200.00	75,400.00	164,000.00
Transaction cost 10%	6,720.00	45,240.00	98,400.00
Total construction cost	73,920.00	497,640.00	1,082,400.00
Construction cost (Baht/cubic-meter)	2.03	4.54	5.93
Construction cost (Baht/unit)	5.23	8.79	7.65
Operating and Maintenance cost(Baht/year)			
Maintenance	2,500.00	5,705.00	12,600.00
Electricity system and piping (c)	-	-	-
Chemical (lime)	-	-	-
Officer	1,200.00	2,500.00	40,000.00
Total operating and maintenance	3,700.00	8,205.00	52,600.00
Operating and Maintenance cost(Baht/cubic-meter)	1.01	0.75	2.88
Operating and Maintenance cost(Baht/unit)	2.62	1.45	3.72
Total cost (Baht/unit)	7.84	10.24	11.37

[a] Upflow Anaerobic Sludge Blanket, [b] Facultative Pond, [c] Maturation Pond

Source: PCD (2003a).

Table 3-10: Cost and revenue of pig farm production

B.E.	Variable cost	Fixed cost	Total cost		Price	Revenue
			Baht/unit	Baht/Kg	Baht/Kg	Baht/Kg
2527	2,242.63	52.81	2,295.44	22.95	21.74	(1.21)
2528	1,707.58	81.86	1,789.44	17.89	17.00	(0.89)
2529	1,575.63	56.51	1,632.14	16.32	19.15	2.83
2530	1,927.56	57.28	1,984.84	19.85	22.11	2.26
2531	2,246.60	70.67	2,317.27	23.17	25.96	2.79
2532	2,367.41	79.08	2,446.49	24.46	28.17	3.71
2533	2,261.67	83.84	2,345.51	23.46	24.92	1.46
2534	2,238.12	74.34	2,312.46	23.12	30.00	6.88
2535	2,658.15	73.34	2,731.49	27.31	31.31	4.00
2536	2,301.19	62.69	2,363.88	23.64	23.75	0.11
2537	2,202.44	64.68	2,267.12	22.67	26.70	4.03
2538	2,849.18	67.12	2,916.30	29.16	35.21	6.05
2539	3,237.73	70.17	3,307.90	33.08	40.57	7.49
2540	3,529.66	78.28	3,607.94	36.08	39.07	2.99
2541	3,497.55	80.74	3,577.62	35.78	41.65	5.87

Source: PCD (2003a).

b) Urban communities

The Ministry of Natural Resources and Environmental declaration issued in 2/2546 has stipulates that every household in each community have to pay a wastewater treatment charge. Thus, treatment charge rates from the Ministry of Natural Resources and Environment are used The table 3-11 is shown below.

Table 3-11: Evaluated operating cost of stabilization pond in each local government

No.	Municipality	Current volume of wastewater treatment (cubic meter/day)	Current volume of wastewater treatment (cubic-meter/year)	Operating and Maintenance cost (Million Baht/year)	Current operating cost (Baht/cubic-meter)	Evaluated operating cost (Baht/cubic-meter)
1	District U-thong, Suphanburi province	3,500	1.28	0.39	0.31	0.40
2	Mueng Rajburi	17,000	6.21	2.19	0.35	0.46
3	Varin-chumrab, ubomratchathani province	2,896	1.06	0.40	0.38	0.49
4	Mueng Chanthaburi	5,000	1.83	0.86	0.47	0.61
5	City municipal of Nakorn prathom province	15,000	5.48	2.80	0.51	0.66
6	City municipal of Nakornratchasrima province	50,884	18.57	9.79	0.53	0.69
7	Mueng Kumpaeng-phet	2,500	0.91	0.60	0.66	0.85
8	Mueng Baan-mee	600	0.22	0.15	0.68	0.89
9	Mueng Chainat	2,500	0.91	0.70	0.77	1.00
10	Mueng Tak	2,903	1.06	0.83	0.78	1.02
11	Mueng Panus-nikom	2,000	0.73	0.65	0.89	1.16
12	Mueng Hat yai	50,000	18.25	17.52	0.96	1.25
13	District Tha-Raae, Sakolnakorn province	958	0.35	0.34	0.97	1.26
14	Mueng Suphanburi	2,000	0.73	0.80	1.10	1.42
15	Mueng Payao	3,598	1.31	1.86	1.42	1.84
16	Mueng Sakolnakorn	7,295	2.66	3.84	1.44	1.87
17	Mueng Nan	1,400	0.51	0.81	1.59	2.06
18	District Pakchong	2,000	0.73	1.25	1.71	2.23
19	District Huakwang, Mahasarakham province	600	0.22	0.51	2.33	3.03
20	Mueng Phetburi	3,500	1.28	3.55	2.78	3.61

Source: PCD (2003b).

Remark: Other municipals in each province referred to the regulation of Municipality of Amphoe Mueng

Table 3-12: Evaluated operating cost of aerated lagoon in each local government

No.	Municipality	Current volume of wastewater treatment		Operating and Maintenance cost	Current operating cost	Evaluated operating cost
		(cubic meter/day)	(cubic-meter/year)	(Million Baht/year)	(Baht/cubic-meter)	(Baht/cubic-meter)
1	Mueng Nondhaburi	20,000	7.3	7.93	1.09	1.41
2	Mueng Pattaya(wat bun)	5,500	2.01	2.57	1.28	1.66
3	Mueng Pa-tong	6,500	2.37	3.15	1.33	1.73
4	District pra-in racha, Ayuthaya province	1,900	0.69	0.96	1.38	1.8
5	Mueng Laem chabang	1,450	0.53	0.78	1.47	1.92
6	Mueng Pattaya(Na kluea)	50,000	18.25	28.44	1.56	2.03
7	Mueng Phuket	20,443	7.46	12	1.61	2.09
8	Meung Kanchanaburi	12000	4.38	8.2	1.87	2.43
9	Mueng Chacheungsao	3,000	1.1	2.11	1.93	2.51
10	Provincial local government, Chonburi	10,315	3.76	7.69	2.04	2.66
11	District Baan paae	941	0.34	0.72	2.1	2.73
12	Mueng Saensuk north-west	17,131	6.25	16	2.56	3.33
13	Mueng Potharam	2500	0.91	2.6	5.85	3.7
14	City Pranakorn Sriayuthaya	1,500	0.55	2	3.65	4.75

Source: PCD (2003b).
Remark: Other municipals in each province referred to the regulation of Municipality of Amphoe Mueng

Table 3-13: Evaluated operating cost of activated sludge in each local government

No.	Municipality	Current volume of wastewater treatment		Operating and Maintenance cost	Current operating cost	Evaluated operating cost
		(cubic meter/day)	(cubic-meter/year)	(Million Baht/year)	(Baht/cubic-meter)	(Baht/cubic-meter)
1	City Trang	6,500	2.37	1.63	0.69	89.00
2	Mueng Burirum	6,500	2.37	2.02	0.85	1.11
3	City Ubon Ratchathani	5,500	2.01	2.92	1.45	1.89
4	District Cha-am, Phetburi province	2,306	0.84	1.54	1.83	2.38
5	City Songkha	5,000	1.83	3.60	1.97	2.56
6	Mueng Prachuabkhirikhun	2,480	0.91	1.91	2.11	2.74
7	City Chieng mai	15,000	5.48	14.37	2.62	3.41

Source: PCD (2003b).
Remark: Other municipals in each province referred to the regulation of Municipality of Amphoe Mueng

The urban community revenue comes from profit per capita. Parameter (P) is derived from public service budget. Social development is supported by the provincial government and can be divided by the provincial population. The quantity (Q) is derived from the population in each sub-district. The revenue of urban community in each sub-basin is derived from (P) multiply by (Q). (P)and (Q) of each province are shown in the table below.

Table 3-14: Total provincial budget of public service, social development and budget per capita, and Current operating abatement cost of each province

Province	Provincial budget for		Total (Baht)	No. of people	Budget per capita (Baht)	Current operating cost (Baht/cubic-metre)
	Public service (Baht)	Social development (Baht)				
Samuth sakorn	73,453,068.00	18,029,153.00	91,482,221.00	449,090.00	203.71	1.09
Suphunburi	190,698,415.00	8,683,323.00	199,381,738.00	868,681.00	229.52	1.10
Chai nat	75,415,999.00	3,596,661.00	79,012,660.00	339,032.00	233.05	0.77
Kanchanaburi	194,293,494.00	1,337,492.00	195,630,986.00	826,169.00	236.79	1.87
Uthaithani	92,063,538.00	270,831.00	92,334,369.00	326,882.00	282.47	0.77
Nakornprathom	169,141,324.00	11,062,003.00	180,203,327.00	798,016.00	225.81	0.51

Source: Bureau of the Budget (2004) and PCD (2003b).

c) Aqua culture

Most of the economic data are from the Development of Effluent Treatment Management for Aquaculture projects, PCD (2005a). The abatement cost for aquaculture can be divided into 2 groups. All fish farms treatment methods refer to the use Aerated Lagoons with Constructed wetlands. All prawn farms treatment methods refer constructed wetlands. The detail of expenses are shown in the table below:

Table 3-15: Abatement cost of each type of aqua culture

Details	Fish	Prawn
Volume of Wastewater (cubic meter/ rai-year)	16,432.00	3,307.20
Aerated Lagoon + Constructed Wetland		
Abatement Cost (Baht/rai- year)	72,210.00	-
Abatement Cost (Baht / cubic meter)	4.39	-
Constructed Wetland		
Abatement Cost (Baht/rai- year)	-	16,000.00
Abatement Cost (Baht/cubic meter)	-	4.84

Source: PCD (2005b).

Table 3-16: Operation cost of each type of aquaculture

Detail	**Cost** (Baht/rai/year)
Operation cost	
Snake-head fish feeding cost	989,250
Nile tilapia feeding cost	5,500
Cat fish feeding cost	116,792
Giant freshwater prawn	38,500

Source: PCD (2005b).

Table 3-17: Revenue of each type of aqua culture

Detail	Price (Baht/kg)	Quantity (kg/rai)	Revenue (Baht/rai-yr)
Benefit			
Sales of Snake-head fish	60.00	21,150.00	1,269,000.00
Sales of Nile tilapia fish	20.00	800.00	16,000.00
Sales of Cat fish	25.00	6,742.00	168,550.00
Sales of Giant freshwater prawn	250.00	-	51,708.00

Source: PCD (2005b).

d) Industry

There are 44 types of factory along the Thachin river giving a total of 8,160 factories. In arriving at the abatement cost, we investigated the wastewater treatment processing systems of each factory from the Department of Industry. The expense for each processing referred to the average expense was obtained from the research of “The Standard of Wastewater Treatment Charge, (2003c)”

Revenue section, the net profit per ton of whole industrial type, referred to table 202 of I/O model (Office of the National Economic and Social Development Board), divided by the Quantity of National Production (tons) (information comes from the Ministry of Industry). The profits per production (ton) of each manufacturing type multiplied by Q (number of manufacturers of each type in each sub-basin). Finally, the revenue per unit of each type in each sub-basin are shown in the table below:

Table 3-18: Revenue and Cost of Abatement for each Industrial activity

No	Types of industry	Industrial activity	Revenue per ton thousand Baht	Wastewater Technology	Cost of Abatement Baht/cubic meter-day
1	4(1)	Slaughtering	44.86	Sump Area	0.29
	4(2)	The preservation of meat by toast, smoke-dried, pickled, sun-dried and sharply freezing method	44.86	Activated Sludge	3.1
	4(3)	Processed food products from animal meat, fat, hide and grease or born extract	44.86	Septic Tank	0
2	5(5)	Processed cheese and butter	23.33	RBC[a]	1.62
	5(6)	Processed yogurt	23.33	Activated Sludge	3.1
3	6(1)	Processed aquatic animal food and canning	62.56	Aerated Lagoon	1.49
	6(2)	The preservation of aquatic animal by toast, smoke-dried, pickled, sun-dried and sharply freezing method	62.56	Aerated Lagoon	1.49
	6(3)	Processed food product from aquatic animal and hide or fat of aquatic animal	62.56	Activated Sludge	3.1
	6(5)	Sliced, boiled, steamed, fired, and grinded (fish) aquatic animal	62.56	Activated Sludge	3.1
4	7(1)	The extraction of vegetable and animal oils and fats	7.70	Sump Area	0.29
	7(4)	Processed pure vegetable and animals oils and fats	7.70	Activated Sludge	3.1
5	8(1)	Canning of fruit and vegetables	21.45	Sump Area	0.29
	8(2)	Preserving of fruit and vegetables	21.45	Sump Area	0.29
6	9(2)	Processed starch	3.74	Stabilization pond	0
	9(4)	Grain mill products manufacturing	3.74	Sump Area	0.29
7	10(1)	Processed bakeries	48.94	Septic Tank	0
	10(2)	Processed biscuits	48.94	Septic Tank	0
	10(3)	Baked and steamed products manufacturing	48.94	Sump Area	0.29
8	11(2)	Processed sugar refineries	5.21	Sump Area	0.29
	11(6)	Processed glucose, dextrose, fructose and similarly other products	5.21	Activated Sludge	3.1
9	12(9)	Processed chewing gum	23.33	Activated Sludge	3.1
	12(11)	Processed ice-cream	23.33	Septic Tank	0

Table 3-18: (Continued)

No	Types of industry	Industrial activity	Revenue per ton thousand Baht	Wastewater Technology	Cost of Abatement Baht/cubic meter-day
10	13(2)	Processed additive	-	Sump Area	0.29
	13(3)	Processed powder-yeast	-	Sump Area	0.29
11	15(1)	Prepared animal feeds	1.58	Sump Area	0.29
	15(2)	Grinded vegetable, grain, meat, bone and shellfish for animal feeds	1.58	Stabilization pond	0
12	16	Manufacture of distilling rectifying and blending spirits	1.20	UASB[b]	32.95
13	20(1)	Processed drinking water	8.40	Septic Tank	0
	20(2)	Processed non-alcoholic drinks	8.40	Activated Sludge	3.1
14	22(1)	Carbonize incubation, bleaching and dyeing fibers	135.00	Activated Sludge	3.1
	22(2)	Spinning of cotton	135.00	Activated Sludge	3.1
	22(3)	Textile finishing	135.00	Activated Sludge	3.1
	22(4)	Textile printing	135.00	Sump Area	0.29
15	24	Knitting mills	135.00	Activated Sludge	3.1
16	30	Manufacture of fur dressing and dyeing	12.07	Activated Sludge	3.1
17	38(2)	Processed paper or fiberboard	9.71	Activated Sludge	3.1
18	42(1)	Processed chemicals	17.16	Sump Area	0.29
19	43(1)	Processed fertilizer and pesticides	-	Septic Tank	0
20	44	Synthetic resin rubber, plastic or synthetic fiber manufacturing	5.99	Activated Sludge	3.1
21	45(1)	Processed paints	-	Activated Sludge	3.1
22	46(1)	Objects which are accepted in medicine text book manufacturing	398.43	Septic Tank	0
	46(2)	Objects which cure, relieve and protect disease for human or animal manufacturing	398.43	Septic Tank	0
23	47(1)	Processed soap and cleaning preparations	14.39	Septic Tank	0
	47(3)	Processed cosmetics	14.39	Septic Tank	0
24	48(6)	Ink or carbon black manufacturing	-	Sump Area	0.29
25	50(4)	Processed miscellaneous petroleum	0.13	Sump Area	0.29
26	52(3)	Smoked rubber, crepe rubber, sticky rubber and liquid rubber manufacturing	5.99	Stabilization pond	0
	52(4)	Processed natural rubber product or synthetic rubber	5.99	Sump Area	0.29

Table 3-18: (Continued)

No	Types of industry	Industrial activity	Revenue per ton thousand Baht	Wastewater Technology	Cost of Abatement Baht/cubic meter-day
27	54	Grass and fiberglass manufacturing	1.69	Sump Area	0.29
28	55	Manufacture of tile, pottery or ceramic	27.90	Sump Area	0.29
29	59	Smelt, melt, mold, press out, haul or produce iron or primary steel (Iron and steel basic)	7.57	Sump Area	0.29
30	60	Smelt, mix, purify, melt and mold (Non-ferrous metal basic)	50.23	Sump Area	0.29
31	92	Manufacture of frozen	-	Activated Sludge	3.1
32	98	Laundries, laundry services and cleaning and dyeing plant	-	Activated Sludge	3.1
33	101	Central waste treatment plant	-	Activated Sludge	3.1

[a] Rotating Biological Contactor, [b] Upflow Anaerobic Sludge Blanket

Source: Database of Department of Industrial Work (2006), Office of Industrial Economics (2006), National Economics and Social Development Board (2006), PCD (2003c).

Table 3-19: The necessary parameters of database collection

Details	Unit
Current situation of BOD loading in Thachin river	
- Volume of wastewater treatment(F)	Cubic-metre
- Pollution concentration in infuent stream(I)	Kg-BOD/Cubic-metre
- An ability of pollution release in any point source(alpha)	
Total Maximum Daily Loading, target of emission reduction	
- Total Maximum Daily Loading	Kg-BOD/day
- % Reduction in any subbasin	Percentage
Pig farm	
- Cost of abatment of any wastewater treatment technology	Bant/Cubic-metre
- Profit per pig unit (100 kg)	Baht
- Quantity of number of pig unit in any subbasin	Unit
- Pollution concentration in effluent stream(E) (depend on treatment technology)	Kg-BOD/Cubic metre

Table 3-19: (continued)

Details	Unit
Urban community	
- Cost of abatment of any local government	Bant/Cubic-metre
- Received budget per capita	Baht
- Number of people in each subbasin	Unit
- Pollution concentration in effluent stream(E) (depend on expected treatment technology)	Kg-BOD/Cubic metre
Aqua culture	
- Cost of abatment of any wastewater treatment technology	Bant/Cubic-metre
- Profit per unit of aqua culture area	Baht
- Quantity of aqua culture area in any subbasin	Unit
- Pollution concentration in effluent stream(E) (depend on expected treatment technology)	Kg-BOD/Cubic metre
Industry	
- Cost of abatment of any wastewater treatment technology	Bant/Cubic-metre
- Profit per unit of industrial type	Baht
- Quantity of any industrial type in any subbasin	Unit
- Total revenue from industrial production in any subbasin	Baht
- Pollution concentration in effluent stream(E) (depend on expected treatment technology)	Kg-BOD/Cubic metre

3.2.2 Phase II: Development of MAC for each main point source and Calculated Tax rate equivalent to CAC

In this phase, the data collection can be divided into 2 groups which are (a) marginal abatement cost function and (b) Non-Uniform tax from any main point sources of 18 sub-basins. More details are shown below:

3.2.2.1 Data collection

1. Finding volume of wastewater treatment (F), pollution concentration in the influent stream (I), pollution concentration in the effluent stream (E) of whole river for each activity.
2. Synthesis co-efficient of abatement cost, function equation (3-1)
3. Separated F, I, E of each sub-basins. Each sub-basin is separated for each activity. Finally, arriving at the total value of F, I, E for each sub-basin and related activities
4. Emission reduction targets
5. Abatement costs

3.2.2.2 Data analysis

The marginal Abatement Cost function is a non-linear regression program which is selected to input the economic data set from the required economic criteria. The idea of a marginal abatement cost curve (MAC) comes from company or plant level models of reducing pollution. In production theory, the interpretation is straightforward. Given that certain activities in the production process lead to pollutions of undesired substances and considering certain abatement technologies. The marginal abatement costs represents either the marginal loss in profits from avoiding the last unit of emissions or the marginal cost of achieving a certain pollution target from a certain level of output. Whereas the latter focuses on abatement technologies such as air or water filters, the former concept is more interesting in the overall adjustment of a company to an emission constraint including adjustments in the output levels (McKitrick, 1999).

The results of phase II and phase III are divided into 2 scenarios. First, is the emission tax rate for each main point sources of each sub basin (Non-uniform tax), and secondly is a single emission tax rate for each sub basin (Uniform tax). The procedures to calculate effluent variation taxes are as follows:

1. Using F, I, E and C for each main point source of the entire Thachin river from phase I in order to run the regression in E-view program. Finding the coefficient set of abatement cost equation of each main point source.

   Cost of abatement equation:

$$C= e^{a} F^{b} I^{c} E^{d} \tag{3-1}$$

   Where C is the cost of abatement,

   'e' is natural logarithm,

   'F' is volume of waster water treatment,

   ' I' is pollution concentration in influent stream,

   'E' is pollution concentration in effluent stream.

   and 'a', 'b', 'c', and 'd' are coefficient sets (Mehta, S., 1997)

2. Creating the marginal abatement cost function. By a partial derivative cost of abatement equation by 'E'

$$C = e^{a} F^{b} I^{c} E^{d} \tag{3-2}$$

take log

$$LnC = a + bLnF + cLnI + dLnE \tag{3-3}$$

$$\frac{d}{dE} C = e^{a} F^{b} I^{c} (-d) E^{d-1} \tag{3-4}$$

$$Tax = MC = e^{a} F^{b} I^{c} (-d) E^{d-1} \tag{3-5}$$

3. Creating a calculation sheet to find the tax variation of each main activity in each sub basin. By including the data of each parameter into the equation 3-5. Derivative of abatement cost equal to marginal abatement costs and equal to tax rates as shown in the figure above.

   Where;

   F = Total volume of wastewater treatment of each main point source at each sub basin in scenario one and equal to total volume of wastewater treatment of each sub basin in scenario two,

   I = Total pollution concentration in influent stream of each main point source at each sub basin in scenario one and equal to total pollution concentration in influent stream of each sub basin in scenario two,

   E = I – (I * % target of emission reduction),

   Percentage of target of emission reduction = ((I – TMDL)*100)/I

   and ‘a’, ‘b’, ‘c’, are co-efficient sets.

3.2.3 Phase III. Mathematical decision-making model

3.2.3.1 Data collection

a) Allowable pollution loading in each sub-basin (at source) is the sum of the maximum pollution loading without deteriorating the river. This value comes from the database collection in phase I which was explained previously.
b) Revenue per product unit of each main point source is the difference for the section on economics of significant pollution.
c) Product quantity of each significant production in every sub-basin.
d) Effluent Variation tax for each product in each sub-basin. This value came from the phase II results
e) Emitted Emissions after tax charges has been added for every product in each sub-basin
f) Emission sources in each product have been emitted into each sub-basin before passing treatment system.
g) The effluent volume emitted from each product in each sub-basin
h) An ability of pollution emission in each production type
i) An ability of wastewater per each production unit
j) Co-efficient set of each main point source.

3.2.3.2 Data analysis

a) Econometric

Literally interpreted, econometrics means "economic measurement ." Although measurement is an important part of econometrics, the scope of econometrics is much broader, as can be seen from the following quotations (Gujarati, 2003):

Econometrics, the result of a certain outlook on the role of economics, consists of the application of mathematical statistics to economic data to lend empirical support to the models constructed by mathematical economics and to obtain numerical results (Tintner, 1968)

…econometrics may be defined as the quantitative analysis of actual economic phenomena based on the concurrent development theory and observation, related by appropriate methods of inference (Samuelson et al., 1954)

Econometricians…are a positive help in trying to dispel the poor public image of economics (quantitative or otherwise) as a subject in which empty boxes are opened by assuming the existence of can-openers to reveal contents which any ten economists will interpret in 11 ways (Darnell, 1990)

This model is created on the basis that the government has to set up taxes for each sub-basin. The models response to the limiting conditions or constants in the environment. The environmental constants meet the standard requirements and the expected profit of the main point sources activities are not zero.

In this research, econometrics are used for converting the qualitative data into quantitative data and to describe the relation of all attributes in mathematic equations in order to develop a mathematical decision making model. The details are shown in section 4.4

b) Excel Solver

What is optimization?

When we want to know how much maximized benefit is produced when these companies are limited by certain constraints (environmental and economic constraints as show in section 4.4: Mathematical Decision Making model)

In this situation, we want to find the values of certain cells in a spreadsheet that optimizes certain objectives which the Excel Solver tool assists in solving optimization problems.

Defining an optimization model.

An optimization model has three parts : i. the target cell, ii. the changing cells, and iii.the constraints.

i. Target cell

The target cell represents the objective or goal which on needs to either minimize or maximize, thus measuring profitability.

ii. Changing cells

Changing cells are those that are changed or adjusted to optimize the target cells. In this model these cells are the yearly volumes of each pollution unit produced from each main point source.

iii. Constraints

Constraints are restrictions place on the changing cells. In this model, the pollution is released within allowable loadings that meet water classification standards. In most Solver models, there is the implicit constraint that all changing cells must be non-negative.

In this mathematical decision making model, 'Target' is set at maximization value of system profit of each sub basin. By changing the emission release cells, to study the effect of tax charges on how much volume of emission is polluted by each main point source. While as any result of target and changing cells is limited by the constraints which are set in the model.

The mathematical decision making model's results as show;

- Gross profit of each sub basin
- Total effluent pollution of each sub basin
- Allowable pollution loading in each subbasin
- Revenue of each main point source
- Cost of abatement of each main point source at each sub basin
- Tax expense of each main point source at each sub basin
- Effluent pollution of each main point source at each sub basin
- Total expense of each main point source at each sub basin
- Profit of each main point source at each sub basin

The description of Non-uniform and Uniform tax

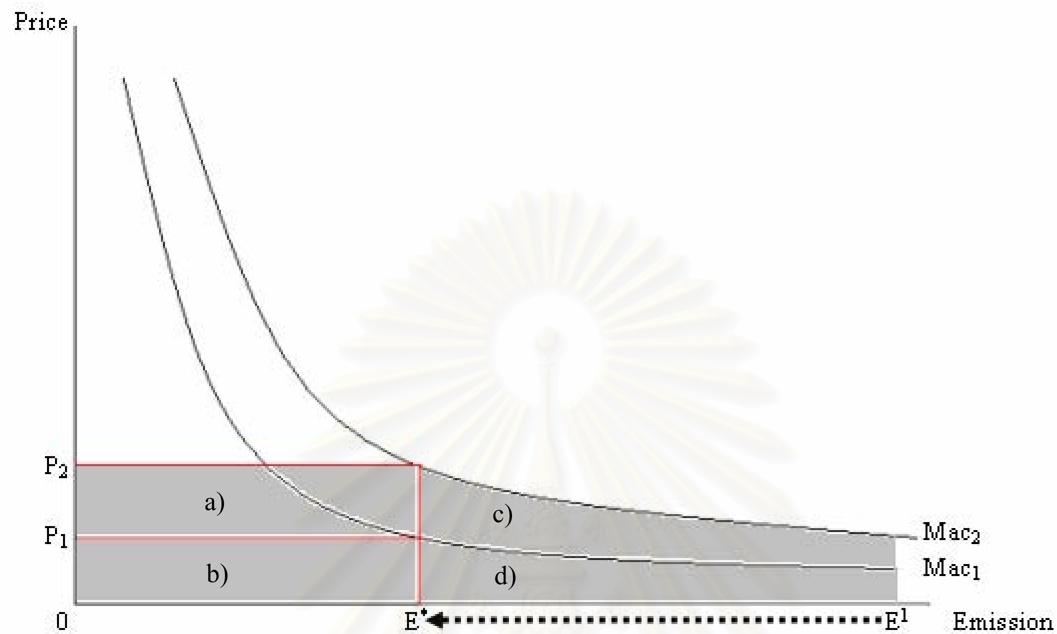

Figure 3-11: Non-uniform tax equivalent to CAC

In this research, If Non-uniform tax is adopted, Non-uniform tax would require from Thailand government to control of pollution discharge of all activities.

The cost of each main point source is not equal. The government, thus, need each main point source to reduce their effluent from E^1 to E* by appointed point source 1 has marginal abatement cost function at mac1 and main point source 2 has marginal abatement cost function at mac2. The government, then, should collect tax of main point source 1 at P1 and collect tax of main point source 2 at P2. The cost of abatement of main point source 1 is equal to the area of *d* and tax expense of main point source 1 is equal to the area of *b*. And the cost of abatement of main point source 2 is equal to the area of *c* + *d* and tax expense is equal to the area of *a* +*b*

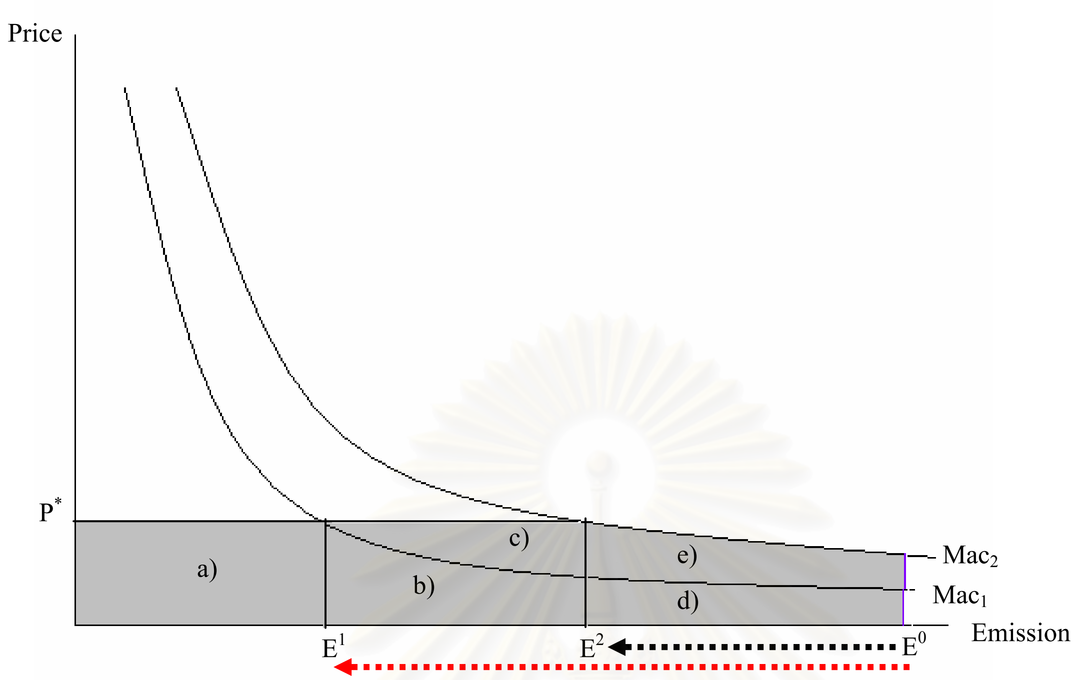

Figure 3-12: Uniform tax

In this research, If uniform tax is adopted, the government requirement to allowable the effluent discharge is to set up the total amount of pollution loading of all activities which should not excess than ambient of water quality. Thus, Tax rate is equal to $MAC_1 = MAC_2$. The result is that main point source1 has the cost of abatement equal to the area of *b* + *d* and tax expense is equal to *a*, main point source2 has the cost of abatement equal to the area *e* + *d* and tax expense is equal to *a* + *b* +*c*.

Thus, applied the uniform tax follow the theorem. The ambient water quality reduce equally each sub-basin, however, each activities reduce unequally pollution depend upon the economic efficient of each sub-basin which sub-basin has higher economic efficient the more reduced pollution have to be done.

The point where $MAC_1 = MAC_2$ = Emission Charge indicated the least-cost allocation of abatement responsibilities across the two polluters and satisfied the requirement for equi-marginal principle of optimality (Callan and Thomas, 1996).

Applied Mathematical Decision-making model into 2 Scenario

The results are divided into two scenarios: (1) first scenario is using Non-Uniform Tax (variation tax) for each main point source in each sub basin and (2) second scenario is using Uniform tax for entire main point source in each sub basin. The scope of the problem for each scenario is presented below.

<u>Case 1:</u> Non-Uniform Tax

- The government forces the polluter to reduce their effluent by imposing Non-Uniform tax rates to charge each main point source in each sub basin (Profit maximization).
    - Using Excel Solver to investigate
        - Main point sources pollution at each sub basin
        - Profit of each main point source
        - Abatement cost and tax expenses

<u>Case 2</u>: Uniform Tax

- Government sets the minimum effluent tax which brings sub-basin emissions lower than the sub-basin effluent standard levels. (Profit maximization)
    - Using Excel Solver to investigate
        - Uniform Tax
        - Main point sources pollution at each sub basin
        - Profit of each main point source
        - Abatement cost and tax expenses

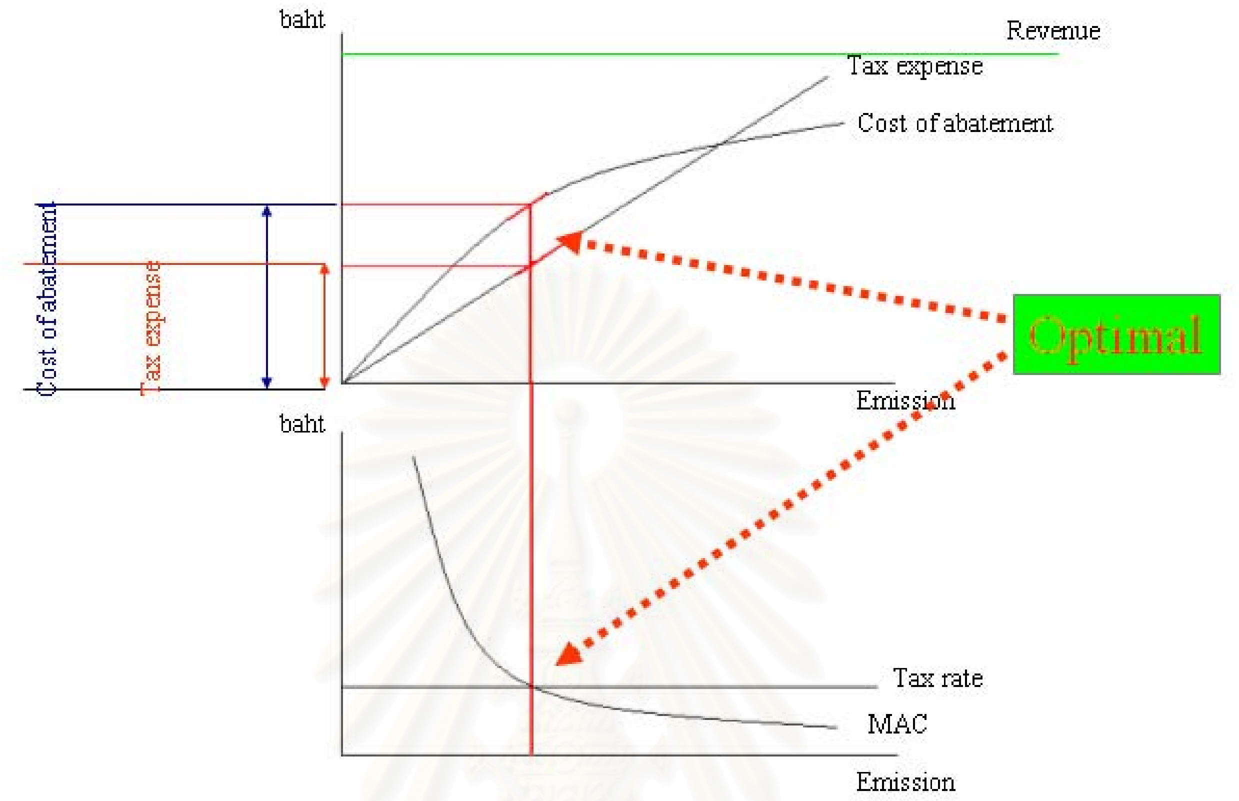

Figure 3-13: The optimal case of tax charge at total cost curve and marginal abatement cost curve

How optimization Mathematical Decision-making model work with excel solver

Case 1: Non-Uniform Tax

1. $$\prod_i = \sum_{k=1}^{N} PQ_k - \sum_{k=1}^{N} ABC_k - T\sum_{k=1}^{N} E_k$$

Finding the Maximized benefits which are involved in ‘E’ for Abatement cost (Cost $=e^aF^b I^c E^d$) and Tax expense (TE)

2. When reducing ‘E’ for one unit. Tax expenses decrease for ‘T’ Baht, while cost abatement increases MAC Baht.
3. Whenever reducing ‘E’ and ‘T’ Baht is greater than MAC Baht, the model will continue decreasing ‘E’ until the last unit of ‘E’ makes value of MAC Baht > T Baht. The model will stop decreasing ‘E’. At that point T = MAC then profit is maximized.

<u>Case 2:</u> Uniform Tax

1. Uniform Tax is a single tax rate where MAC values in every activity are equal and profits maximized, where T = MAC
2. Uniform Tax = $MAC_1 = MAC_2 = MAC_3 = MAC_4$
   and pollutant loading must not exceed the standard.
3. We have to find the least uniform tax rate = $MAC_1 = MAC_2 = MAC_3 = MAC_4$ and pollution must not exceed the standard (Callan and Thomas, 1996).

CHAPTER IV

MATHEMATICAL DECISION-MAKING MODEL

4.1 Surface water quality control: Mathematical Decision-Making model

Objective functions:

The objective function is considered for the problem which is the maximization of system profits.

$$\text{Maximize} \prod_{j=1}^{N} = \prod_{pj} + \prod_{uj} + \prod_{aj} + \prod_{ij} \quad (4\text{-}5)$$

Where $\prod_{j=1}^{N}$ is the system profit in sub-basin. $\prod_{pj}$ is the system profit of an entire pig farm that already includes social costs in sub-basin 'j'. This social cost is represented by abatement costs added to a function. In the same way, $\prod_{uj}$ is system profit of the entire urban communities in sub-basin 'j'. $\prod_{aj}$ is the system profit of an entire aqua culture. $\prod_{ij}$ is the system profit of an entire industry.

Subject to:

Sub basin pollution:

$$E_j = \sum_{k=1}^{N} E_{pjk} + \sum_{k=1}^{N} E_{ujk} + \sum_{k=1}^{N} E_{ajk} + \sum_{k=1}^{N} E_{ijk} \quad (4\text{-}6)$$

Where 'E_j' is the pollution concentration of the entire effluent in sub-basin 'j'. $\sum_{k=1}^{N} E_{pjk}$ is the summation of pollution concentration of an entire pig farm effluent in sub-basin 'j'. $\sum_{k=1}^{N} E_{ujk}$ is the summation of pollution concentration of an entire urban communities effluent in sub-basin 'j'. $\sum_{k=1}^{N} E_{ajk}$ is the summation of pollution concentration of an entire aquaculture effluent in sub-basin ‘j’. $\sum_{k=1}^{N} E_{ijk}$ is the summation of pollution concentration of an entire industrial effluent in sub-basin ‘j’.

Sub-basin pollution constraint:

The most common requirement of pollution control is assuring the pollution loading throughout the river system in an attempt to satisfy and maintain the water classification standard. Specifically, pollution concentrations must be less than the standard limit. Each control point and discharge location becomes a constraint in a mathematical programming model. In a general framework, a typical water quality constraint would be as follows:

$$A_j = E_j + \gamma A_{j-1} \qquad (4\text{-}7)$$

and
$$A_j^* \geq A_j \qquad (4\text{-}8)$$

Sources: Modified from Handley et al., (1997).

Where ‘ A_j ’ is the total pollution concentration of an entire effluent in sub-basin ‘j’, ‘ E_j ’ is the pollution concentration of an entire effluent in sub-basin ‘j’, ‘ γ ’ (transfer coefficient) is the pollution concentration effective of sub-basin ‘j-1’ affected by pollution concentrations of sub-basin j, ‘ A_{j-1} ’ is the total pollution concentration of an entire effluent in sub-basin ‘ j-1’, and ‘ A_j^* ‘ is the required water classification standard or allowable pollution daily loading at sub-basin ‘j’.

Production benefit constraint:

These constraints are defining the acceptable profit level of a production type. The capital cost, variable costs, and abatement costs exist in the production process. When the taxation system is added to the costs, this financial burden is not the cause of a business going bankrupt. At least, the minimum profit level must be more than the break-even point of production. Thus, the profit level of each industry can be formulated as

$$\pi > 0 \tag{4-9}$$

Where π is a benefit in this model.

4.4.1 Pig farm

Pig farm production:

$$\prod_{pj} = \sum_{k=1}^{N} P_p Q_{pjk} - \sum_{k=1}^{N} ABC_{pjk} - T_{pjk} \sum_{k=1}^{N} E_{pjk} \tag{4-10}$$

Where $\prod_{pj}$ is the system profit of the entire pig farm production in sub-basin 'j', $\sum_{k=1}^{N} P_p Q_{pjk}$ is the summation of pig farm production prices per unit multiplied with the quantity of pig farm production unit at farm 'k' in sub-basin 'j'. $\sum_{k=1}^{N} ABC_{pjk}$ is the summation of abatement cost functions of pig farms at farm 'k' in sub-basin 'j'. $T_{pjk} \sum_{k=1}^{N} E_{pjk}$ the charges system of pig farm at farm 'k' in sub-basin 'j' multiplied by the effluent pollution of pig farms at farm 'k' in sub-basin 'j'.

Abatement cost function:

$$ABC_{pjk} = e^{a} W_{pjk}^{bp} I_{pjk}^{cp} E_{pjk}^{dp} \tag{4-11}$$

Source: Modified from Metha et al., (1997)

Where 'ABC_{pjk}' is the abatement cost function of pig farm at farm 'k' in sub-basin 'j'. 'e' = natural logarithm, 'W_{pjk}' is the quantity of treated water of pig farm at farm 'k' in sub-basin 'j'. 'I_{pjk}' is the pollution concentration in the influent treated water of pig farm at farm 'k' in sub-basin 'j'. 'E_{pjk}' is the pollution concentration in the effluent treated water of pig farm at farm 'k' in sub-basin 'j'. 'a',' bp', 'cp', and 'dp' are coefficient parameters of pig farms.

Volume of wastewater per production unit:

$$F_{pjk} = \alpha_p Q_{pjk} \tag{4-12}$$

Where 'F_{pjk}' is the volume of wastewater of pig farm at farm 'k' in sub-basin 'j'. 'α_p' is the ability of wastewater production per pig farm unit. 'Q_{pjk}' is the quantity of pig farm production units at farm 'k' and sub-basin 'j'.

Influent pollution concentration:

$$I_{pjk} = \beta_p Q_{pjk} \tag{4-13}$$

Where 'I_{pjk}' is the pollution concentration in the influent treated water of pig farm at farm 'k' in sub-basin 'j'. 'β_p' is the capacity of pollution released at pig farm. 'Q_{pjk}' is the quantity of pig farm production unit at farm 'k' in sub-basin 'j'.

Pig farm pollution constraint:

$$E_{pjk} \le \bar{E}_{pj} \tag{4-14}$$

Where 'E_{pjk}' the pollution concentration in the effluent treated water of pig farm at farm 'k' in sub-basin 'j'. '$\bar{E}_{pj}$' is the required water classification standard of pig farm in sub-basin 'j' or permitted pollution loading of pig farm in sub-basin 'j'.

4.4.2 Urban community

Urban community production:

$$\prod_{uj} = \sum_{k=1}^{N} P_u Q_{ujk} - \sum_{k=1}^{N} ABC_{ujk} - T_{ujk} \sum_{k=1}^{N} E_{ujk} \tag{4-15}$$

Where $\prod_{uj}$ is the system profit of the entire urban community production in sub-basin 'j'. $\sum_{k=1}^{N} P_u Q_{ujk}$ is the summation of urban community prices per production unit multiplied by the quantity of urban community production unit at community 'k' in sub-basin 'j', $\sum_{k=1}^{N} ABC_{ujk}$ is a summation of the abatement cost function of urban community at community 'k' and sub-basin 'j'. $T_{ujk} \sum_{k=1}^{N} E_{ujk}$ is the charges system of urban community at community 'k' and sub-basin 'j' multiplied by the effluent pollution of urban community at community 'k' and sub-basin 'j'.

Abatement cost function:

$$ABC_{ujk} = e^{a} W_{ujk}^{bu} I_{ujk}^{cu} E_{ujk}^{du} \tag{4-16}$$

Source: Modified from Metha et al., (1997)

Where 'ABC_{ujk}' is the abatement cost function of the urban community at community 'k' and sub-basin 'j'. 'e' = natural logarithm, 'W_{ujk}' is the quantity of treated water of urban community at community 'k' and sub-basin 'j'. 'I_{ujk}' is the pollution concentration in the influent treated water of urban community at community 'k' and sub-basin 'j'. 'E_{ujk}' is the pollution concentration in the effluent treated water of urban community at community 'k' and sub-basin 'j'. 'a','bu', 'cu', and 'du' are the coefficient parameters of urban community.

Amount of wastewater per production unit :

$$F_{ujk} = \alpha_u Q_{ujk} \tag{4-17}$$

Where ‘ F_{ujk} ’ is the amount of urban community wastewater at community ‘k’ in sub-basin ‘j’. ‘ α_u ’ is the wastewater production capacity per urban community unit. ‘ Q_{ujk} ’ is the quantity of urban community production unit at community ‘k’ in sub-basin ‘j’.

Influent pollution concentration:

$$I_{ujk} = \beta_u Q_{ujk} \tag{4-18}$$

Where ‘ I_{ujk} ’ is the pollution concentration in the influent treated water of urban community at community ‘k’ in sub-basin j, ‘ β_u ’ is the pollution release capacity of the urban community. ‘ Q_{ujk} ’ is the urban community production unit at community ‘k’ in sub-basin ‘j’.

Urban community pollution constraint:

$$E_{ujk} \leq \bar{E}_{uj} \tag{4-19}$$

Where ‘ E_{ujk} ’ is the pollution concentration in the effluent treated water of urban community at community ‘k’ and sub-basin ‘j’. ‘ $\bar{E}_{uj}$ ’ is the required water classification standard of urban community in sub-basin ‘j’ or the permitted pollution loading of urban community at sub-basin ‘j’.

4.4.3 Aquaculture

Aquaculture production:

$$\prod_{aj} = \sum_{k=1}^{N} P_a Q_{ajk} - \sum_{k=1}^{N} ABC_{ajk} - T_{ajk} \sum_{k=1}^{N} E_{ajk} \qquad (4\text{-}20)$$

Where $\prod_{aj}$ is the system profit of the entire aquaculture production at sub-basin 'j'. $\sum_{k=1}^{N} P_a Q_{ajk}$ is the summation of aquaculture production prices per unit multiplied by the quantity aquaculture production unit at source 'k' in sub-basin 'j'. $\sum_{k=1}^{N} ABC_{ajk}$ is the summation of abatement cost functions of aquaculture at source 'k' in sub-basin 'j'. $T_{ajk} \sum_{k=1}^{N} E_{ajk}$ are the charges system of aquaculture at source 'k' in sub-basin 'j' multiplied by the effluent pollution of aquaculture at source 'k' in sub-basin 'j'.

Abatement cost function:

$$ABC_{ajk} = e^{a} W_{ajk}^{ba} I_{ajk}^{ca} E_{ajk}^{da} \qquad (4\text{-}21)$$

Source: Modified from Metha et al., (1997)

Where 'ABC_{ajk}' is the abatement cost function of aquaculture at source 'k' in sub-basin 'j'. 'e' = natural logarithm. 'W_{ajk}' is the quantity of treated water of aquaculture at source 'k' in sub-basin 'j'. 'I_{ajk}' is the pollution concentration in the influent treated water of aquaculture at source 'k' in sub-basin 'j'. 'E_{ajk}' is the pollution concentration in the effluent treated water of aquaculture at source 'k' in sub-basin 'j'. 'a', 'ba', 'ca', and 'da' are coefficient parameters of aquaculture.

Amount of wastewater per production unit :

$$F_{ajk} = \alpha_a Q_{ajk} \tag{4-22}$$

Where ‘ F_{ajk} ’ is the volume of wastewater of aquaculture at source ‘k’ in sub-basin j, ‘ α_a ’ is the wastewater production capacity per aquaculture unit and ‘Q_{ajk} ’ is the quantity of aquaculture production unit at source ‘k’ in sub-basin ‘j’.

Influent pollution concentration:

$$I_{ajk} = \beta_a Q_{ajk} \tag{4-23}$$

Where ‘ I_{ajk} ’ is the pollution concentration in the influent treated water of aquaculture at source ‘k’ in sub-basin ‘j’. ‘ β_a ’ is the pollution release capacity of aquaculture. ‘ Q_{ajk} ’ is the quantity of aquaculture production unit at source ‘k’ in sub-basin ‘j’.

Aquaculture pollution constraint:

$$E_{ajk} \leq \bar{E}_{aj} \tag{4-24}$$

Where ‘ E_{ajk} ’ is the pollution concentration in the effluent treated water of aquaculture at source ‘k’ in sub-basin ‘j’. ‘ $\bar{E}_{aj}$ ’ is the required water classification standard of aquaculture at sub-basin ‘j’ or permitted pollution loading of aquaculture at sub-basin ‘j’.

4.4.4 Industry

Industry production:

$$\prod_{ij} = \sum_{k=1}^{N} P_i Q_{ijk} - \sum_{k=1}^{N} ABC_{ijk} - T_{ijk} \sum_{k=1}^{N} E_{ijk} \tag{4-25}$$

Where $\prod_{ij}$ is the system profit of the entire industry production at sub-basin ‘j’, $\sum_{k=1}^{N} P_i Q_{ijk}$ is the summation of industrial production price per unit multiplied by the quantity of industrial production unit at factory ‘k’ and sub-basin ‘j’, $\sum_{k=1}^{N} ABC_{ijk}$ is the summation of abatement cost functions of industry at factory ‘k’ in sub-basin ‘j’, $T_{ijk} \sum_{k=1}^{N} E_{ijk}$ the charges system of industry at factory ‘k’ and sub-basin ‘j’ multiplied by the effluent pollution of industry at factory ‘k’ in sub-basin ‘j’.

Abatement cost function:

$$ABC_{ijk} = e^{a} W_{ijk}^{bi} I_{ijk}^{ci} E_{ijk}^{di} \tag{4-26}$$

Source: Modified from Metha et al., (1997)

Where ‘ ABC_{ijk} ’ is the abatement cost function of industry at factory ‘k’ in sub-basin ‘j’. ‘e’ = natural logarithm, ‘ W_{ijk} ’ is the quantity of treated water of industry at factory ‘k’ in sub-basin ‘j’. ‘ I_{ijk} ’ is the pollution concentration in the influent treated water of industry at factory ‘k’ in sub-basin ‘j’. ‘ E_{ijk} ’ is the pollution concentration in the effluent treated water of industry at factory ‘k’ in sub-basin ‘j’. ‘a’,’ bp’, ‘cp’, and ‘dp’ are coefficient parameters of industry.

Amount of wastewater per production unit :

$$F_{ijk} = \alpha_i Q_{ijk} \tag{4-27}$$

Where ‘ F_{ijk} ’ is the volume of wastewater of industry at factory ‘k’ in sub-basin ‘j’. ‘ α_i ’ is wastewater production capacity per industry unit. ‘ Q_{ijk} ’ is the quantity of industry production unit at factory ‘k’ in sub-basin ‘j’.

Influent pollution concentration:

$$I_{ijk} = \beta_i Q_{ijk} \tag{4-28}$$

Where I_{ijk} is the pollution concentration in the influent treated water of industry at factory ‘k’ in sub-basin ‘j’. ‘ α_i ’ is the ability of pollution release of industry. ‘ Q_{ijk} ’ is the quantity of industry production unit at factory ‘k’ in sub-basin ‘j’.

Industry pollution constraint:

$$E_{ijk} \leq \bar{E}_{ij} \tag{4-29}$$

Where ‘ E_{ijk} ’ is the pollution concentration in the effluent treated water of industry at factory ‘k’ in sub-basin j, ‘ $\bar{E}_{ij}$ ’ is the required water classification standard of industry in sub-basin ‘j’ or the permitted pollution loading of industry in sub-basin ‘j’.

In summary, the model can be expressed as follows:

Regulatory objective:

$$\text{Maximize} \prod_{j=1}^{N} = \prod_{pj} + \prod_{uj} + \prod_{aj} + \prod_{ij} \tag{4-30}$$

Subject to:

Sub-basin pollution:

$$E_j = \sum_{k=1}^{N} E_{pjk} + \sum_{k=1}^{N} E_{ujk} + \sum_{k=1}^{N} E_{ajk} + \sum_{k=1}^{N} E_{ijk} \tag{4-31}$$

Sub-basin pollution constraint:

$$A_j = E_j + \gamma A_{j-1} \tag{4-32}$$

and $$A_j^* \geq A_j \tag{4-33}$$

Production benefit constraint:

$$\pi > 0 \tag{4-34}$$

Pig farm production:

$$\prod_{pj} = \sum_{k=1}^{N} P_p Q_{pjk} - \sum_{k=1}^{N} ABC_{pjk} - T_{pjk} \sum_{k=1}^{N} E_{pjk} \tag{4-35}$$

Pig farm abatement cost function:

$$ABC_{pjk} = e^a W_{pjk}^{bp} I_{pjk}^{cp} E_{pjk}^{dp} \tag{4-36}$$

Amount of wastewater per production unit :

$$F_{pjk} = \alpha_p Q_{pjk} \tag{4-37}$$

Pig farm influent pollution concentration:

$$I_{pjk} = \beta_p Q_{pjk} \tag{4-38}$$

Pig farm pollution constraint:

$$E_{pjk} \leq \bar{E}_{pj} \tag{4-39}$$

Urban community production:

$$\prod_{uj} = \sum_{k=1}^{N} P_u Q_{ujk} - \sum_{k=1}^{N} ABC_{ujk} - T_{ujk} \sum_{k=1}^{N} E_{ujk} \tag{4-40}$$

Urban community abatement cost function:

$$ABC_{ujk} = e^{a} W_{ujk}^{bu} I_{ujk}^{cu} E_{ujk}^{du} \tag{4-41}$$

Amount of wastewater per production unit :

$$F_{ujk} = \alpha_u Q_{ujk} \tag{4-42}$$

Urban community influent pollution concentration:

$$I_{ujk} = \beta_u Q_{ujk} \tag{4-43}$$

Urban community pollution constraint:

$$E_{ujk} \leq \bar{E}_{uj} \tag{4-44}$$

Aquaculture production:

$$\prod_{aj} = \sum_{k=1}^{N} P_a Q_{ajk} - \sum_{k=1}^{N} ABC_{ajk} - T_{ajk} \sum_{k=1}^{N} E_{ajk} \tag{4-45}$$

Aqua culture abatement cost function:

$$ABC_{ajk} = e^{a} W_{ajk}^{ba} I_{ajk}^{ca} E_{ajk}^{da} \tag{4-46}$$

Amount of wastewater per production unit :

$$F_{ajk} = \alpha_a Q_{ajk} \tag{4-47}$$

Aquaculture influent pollution concentration:

$$I_{ajk} = \beta_a Q_{ajk} \tag{4-48}$$

Aquaculture pollution constraint:

$$E_{ajk} \leq \bar{E}_{aj} \tag{4-49}$$

Industry production:

$$\prod_{ij} = \sum_{k=1}^{N} P_i Q_{ijk} - \sum_{k=1}^{N} ABC_{ijk} - T_{ijk} \sum_{k=1}^{N} E_{ijk} \tag{4-50}$$

Industry Abatement cost function:

$$ABC_{ijk} = e^{a} W_{ijk}^{bi} I_{ijk}^{ci} E_{ijk}^{di} \tag{4-51}$$

Amount of wastewater per production unit :

$$F_{ijk} = \alpha_i Q_{ijk} \tag{4-52}$$

Industry influent pollution concentration:

$$I_{ijk} = \beta_i Q_{ijk} \tag{4-53}$$

Industry pollution constraint:

$$E_{ijk} \leq \bar{E}_{ij}$$

CHAPTER V

RESULTS AND DISCUSSIONS

5.1 Marginal Abatement Cost function and its properties of each source type in each sub basin area.

<u>5.1.1Pig farm</u>

Equation 3-1 is developed with a parameter from data collection, the results show that the estimation function as equation 5-1 and its characteristic at table 5-1.

```
Estimation Command:
=====================
LS(H) LOG (COST) C LOG(F) LOG(I) LOG(E) AR(1)

Estimation Equation:
=====================
LOG(COST) = C(1) + C(2)*LOG(F) + C(3)*LOG(I) + C(4)*LOG(E) + [AR(1)=C(5)]

Substituted Coefficients:
=====================
LOG(COST) = -1.184940371 + 0.7196545134*LOG(F) + 0.5233609931*LOG(I) - 0.1365064184*LOG(E) +
[AR(1)=0.2012589663]                                                                    (5-1)
```

Figure 5-1: Estimation Command, Estimation Equation, and Substituted Coefficients

Table 5-1: Data set for marginal abatement cost function of pig farm

Dependent Variable: LOG(COST)			
Sample(adjusted): 1065			
Variable	**Coefficient**	**Std. Error**	**t-Statistic**
C	-1.18494	0.07391	-16.03272
LOG(F)	0.719655	0.17215	4.180373
LOG(I)	0.523361	0.13938	3.755045
LOG(E)	-0.136506	0.02185	-6.246217
AR(1)	0.201259	0.03314	6.073994
R-squared	0.99442	Mean dependent var	8.208
Adjusted R-squared	0.994398	S.D. dependent var	1.6717

Arriving in Table 5-1, using the total data collection from 1,065 samples of the volume of wastewater treatment (F), Concentration influent stream (I) and Concentration effluent stream (E) use for finding the relationship between F, I, E with Cost of Abatement (C) in the form of linear program technique.

The output found that the co-efficient of volume of wastewater treatment (F) was 0.719655 which, mean if the volume of wastewater treatment changed 1 %, the cost of abatement changed in 0.719655, and t-statistic was 4.180373 indicated that they were positive significant. The coefficient of concentration influent stream (I) was 0.523361 which, mean if the concentration in influent stream changed 1 %, the cost of abatement changed in 0.523361 and t-statistic was 3.755045 indicated that they were positive significant. The coefficient of concentration in effluent steam (E) was -0.136506 which mean if amount of concentration in effluent changed 1 %, the cost abatement changed in -0.136506 which mean if the concentration effluent stream changed 1 unit, the cost of abatement changed in -0.136506 and t-statistic was -6.246217. The result indicated that they were negative significant. The R-squared and adjusted R-squared of pig farm were 0.994420 and 0.994398 respectively.

<u>5.1.2 Urban Community</u>

Equation 3-1 is developed with a parameter from data collection, the results show that the estimation function as equation 5-2 and its characteristic at table 5-2.

Estimation Command:
=====================
LS(H) LOG(COST) C LOG(F) LOG(I) LOG(E) AR(1)

Estimation Equation:
=====================
LOG(COST) = C(1) + C(2)*LOG(F) + C(3)*LOG(I) + C(4)*LOG(E) + [AR(1)=C(5)]

Substituted Coefficients:
=====================
LOG(COST) = -0.2211052255 + 0.8080639203*LOG(F) + 0.472856765*LOG(I) - 0.279286674*LOG(E) + [AR(1)=0.9574446249] (5-2)

Figure 5-2: Estimation Command, Estimation Equation, and Substituted Coefficients

Table 5-2: Data set of marginal abatement cost function of urban community

Dependent Variable: LOG(COST)				
Sample(adjusted): 525				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	
C	-0.221105	0.35932	-0.615349	
LOG(F)	0.808064	0.16629	4.859434	
LOG(I)	0.472857	0.16642	2.841336	
LOG(E)	-0.279287	0.01359	-20.54528	
AR(1)	0.957445	0.01394	68.70269	
R-squared	0.997401	Mean dependent var		9.9076
Adjusted R-squared	0.997379	S.D. dependent var		1.8224

Arriving in Table 5-2, using the total data collection from 525 samples of the volume of wastewater treatment (F), Concentration influent stream (I) and Concentration effluent stream (E) use for finding the relationship between F, I, E with Cost of Abatement (C) in form of linear program technique.

The output found that the co-efficient of the volume of wastewater treatment (F) was 0.808064 which, mean if volume of wastewater treatment changed 1 %, the cost of abatement changed in 0.808064, and t-statistic was 4.859434 indicated that they were positive significant.

The coefficient of concentration influent stream (I) was 0.472857 which, mean if the concentration in influent stream changed 1 %. The cost of abatement changed in 0.472857 and t-statistic was 2.841336 indicated that they were positive significant. The coefficient of concentration in effluent steam (E) was -0.279287 which mean if amount of concentration in effluent changed 1 %, the cost abatement changed in -0.279287 and t-statistic was -20.54528. The result indicated that they were negative significant. The R-squared and adjusted R-squared of urban community were 0.997401 and 0.997379 respectively.

5.1.3 Aqua culture

Equation 3-1 is developed by using a parameter from data collection. The results show that the estimation function as equation 5-3 and its characteristic at table 5-3.

Estimation Command:
=====================
LS(H) LOG(COST) C LOG(F) LOG(I) LOG(E) AR(1)

Estimation Equation:
=====================
LOG(COST) = C(1) + C(2)*LOG(F) + C(3)*LOG(I) + C(4)*LOG(E) + [AR(1)=C(5)]

Substituted Coefficients:
=====================
LOG(COST) = 3.679472766 + 0.4665055163*LOG(F) + 0.5449644505*LOG(I) - 0.01146996687*LOG(E) + [AR(1)=1.000000001] (5-3)

Figure 5-3: Estimation Command, Estimation Equation, and Substituted Coefficients

Table 5-3: Data set of marginal abatement cost function of Aqua culture

Dependent Variable: LOG(COST)				
Sample(adjusted): 3075				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	
C	3.679473	0.00399	921.2608	
LOG(F)	0.466506	1.2E-08	37686663	
LOG(I)	0.544964	1.5E-08	37126864	
LOG(E)	-0.01147	2.3E-09	-4975406	
AR(1)	1	1E-07		
R-squared	1	Mean dependent var		15.5531
Adjusted R-squared	1	S.D. dependent var		1.40396

Arriving in Table 5-3, using the total data collection from 3,075 samples of the volume of wastewater treatment (F), Concentration influent stream (I) and Concentration effluent stream (E) use for finding the relationship between F, I, E with Cost of Abatement (C) in form of linear program technique.

The output found that the co-efficient of the volume of wastewater treatment (F) was 0.466506 which, mean if volume of wastewater treatment changed 1 %, the cost of abatement changed in 0.466506, and t-statistic was 37686663 indicated that they were significant. The coefficient of concentration influent stream (I) was 0.544964 which, mean if the concentration in influent stream changed 1 %, the cost of abatement changed in 0.544964 and t-statistic was 37126864. The result indicated that they were positive significant. The coefficient of concentration in effluent steam (E) was -0.01147 which mean if amount of concentration in effluent changed 1 %. The cost abatement changed in -0.01147 and t-statistic was -4975406. The result indicated that they were significant. The R-squared and Adjusted R-squared of aquaculture were 1 and 1 respectively.

5.1.4 Industry

Equation 3-1 is developed with a parameter from collection, the results show that the estimation function as equation 5-4 and its characteristic at table 5-4.

```
Estimation Command:
=====================
LS(H) LOG(COST) C LOG(F) LOG(I) LOG(E)

Estimation Equation:
=====================
LOG(COST) = C(1) + C(2)*LOG(F) + C(3)*LOG(I) + C(4)*LOG(E)

Substituted Coefficients:
=====================
LOG(COST) = -2.706498807 + 1.3810916*LOG(F) + 0.1691965884*LOG(I) - 0.4072167085*LOG(E)
```

(5-4)

Figure 5-4 : Estimation Command, Estimation Equation, and Substituted Coefficients

Table 5-4: Data set of marginal abatement cost function of industry

Dependent Variable: LOG(COST)			
Sample(adjusted): 8100			
Variable	**Coefficient**	**Std. Error**	**t-Statistic**
C	-2.706499	0.12081	-22.40325
LOG(F)	1.381092	0.03513	39.31115
LOG(I)	0.169197	0.02677	6.319535
LOG(E)	-0.407217	0.0221	-18.4225
R-squared	0.913056	Mean dependent var	9.55385
Adjusted R-squared	0.912868	S.D. dependent var	3.37141

Arriving in Table 5-4, using the total data collection from 8,100 samples of the volume of wastewater treatment (F), Concentration influent stream (I) and Concentration effluent stream (E) use for finding the relationship between F, I, E with Cost of Abatement (C) in form of linear program technique.

The output found that the co-efficient of the volume of wastewater treatment (F) was 1.381092 which, mean if volume of wastewater treatment changed 1 %, the cost of abatement changed in 1.381092, and t-statistic was 39.31115 indicated that they were significant. The coefficient of concentration influent stream (I) was 0.169197 which, mean if the concentration in influent stream changed 1 %, the cost of abatement changed in 0.169197 and t-statistic was 6.319535 indicated that they were not significant. The coefficient of concentration in effluent steam (E) was -0.407217 which mean if amount of concentration in effluent changed 1 %, the cost abatement changed in -0.407217 and t-statistic was -18.4225. The result indicated that they were significant. The R-squared and Adjusted R-squared of industry were 0.913056 and 0.912868 respectively.

5.2 The effluent charge of each significant main point source and entire main point source in each sub-basin

The study found that in each district to use the effluent charge in different rate for the pollution generators are very confuses and hardly to implement. Thus, the Tax charge of every main-point source should be the same in the district.

5.2.1The effluent t charge of each significant main point sources in each sub-basin

5.2.1.1 Pig farm

To control and preserve the water quality standard of Thachin River, the effluent charge of pig farm in each sub-basin has to apply as the table below:

Table 5-5: The effluent charge of pig farm in each sub-basin

Sub basin	Charge (Bath/Kg-BOD)	BOD(Kg/year)		% reduction	Cost of abatement (Bath/year)	Tax expense (Bath/year)
		Influent	Effluent			
LI	0.15	40,870.88	20,435.44	50.00%	22,154.11	3,024.17
RF	0.91	2,084,110.76	312,616.61	85.00%	2,077,580.41	283,602.19
RFm	0.37	988,853.44	296,656.03	70.00%	811,684.66	110,799.83
LP	0.18	31,481.25	12,592.50	60.00%	17,000.76	2,320.71
RG	0.29	1,985,859.15	794,343.66	60.00%	1,693,611.34	231,188.11
LQ	2.16	73,682.55	3,684.13	95.00%	58,290.46	7,957.00
RH	3.33	3,458,866.84	172,943.34	95.00%	4,223,481.10	576,530.51
RI	0.14	823,831.46	576,682.02	30.00%	601,506.25	82,109.21
LS	0.14	685,541.18	514,155.88	25.00%	509,815.52	69,592.88
RJ	0.10	83,636.10	62,727.08	25.00%	47,912.82	6,540.39
RK	0.09	12,592.50	9,444.38	25.00%	6,239.89	851.78
RL	0.10	1,642.50	1,231.88	25.00%	858.43	117.18

Table of 5-5 show that sub-basin LI need to reduce 50% of pollution water. The effluent should be charged at 0.15 Baht / Kg of BOD. The effluent added with cost of abatement was 22,154.11 Baht/year.

5.2.1.2 Urban community

To control and preserve the water quality standard of Thachin River, the effluent charge of urban community in each sub-basin has to apply as the table below:

Table 5-6: The effluent charge of urban community in each sub-basin

Sub basin	Charge (Bath/Kg-BOD)	BOD(Kg/year)		% reduction	Cost of abatement (Bath/year)	Tax expense (Bath/year)
		Influent	Effluent			
LI	3.09	138,631.98	69,315.99	50.00%	766,413.59	214,049.35
RF	14.96	434,537.87	65,180.68	85.00%	3,490,437.18	974,833.73
LJ	3.80	8,218.34	3,698.25	55.00%	50,348.14	14,061.58
LK	3.80	4,900.89	2,205.40	55.00%	29,999.05	8,378.34
LL	3.80	5,244.30	2,359.93	55.00%	32,104.63	8,966.41
RFm	6.42	146,743.26	44,022.98	70.00%	1,011,539.56	282,509.85
LP	4.43	17,969.04	7,187.61	60.00%	113,910.95	31,813.85
RG	4.43	31,648.20	12,659.28	60.00%	200,812.82	56,084.41
LQ	63.37	37,395.92	1,869.80	95.00%	424,234.83	118,483.27
RH	43.99	2,981,167.04	149,058.35	95.00%	23,477,416.59	6,556,937.25
RI	2.12	716,956.59	501,869.62	30.00%	3,813,489.90	1,065,058.15
LS	1.91	594,845.01	446,133.76	25.00%	3,057,571.42	853,939.95
RJ	1.86	196,757.15	147,567.86	25.00%	984,669.23	275,005.31
RK	1.99	133,711.88	100,283.91	25.00%	713,492.18	199,269.09
LT	1.88	55,468.22	41,601.16	25.00%	279,543.15	78,072.77
LU	1.83	588,827.67	441,620.75	25.00%	2,899,785.93	809,872.51
RL	1.89	132,415.02	99,311.27	25.00%	672,919.87	187,937.77

Table 5-6 indicated that sub-basin LI need to reduce 50% of pollution water. The effluent should be charged at 3.09 Baht / Kg of BOD. The effluent added with cost of abatement was 766,413.59 Baht/year.

5.2.1.3 Aquaculture

To control and preserve the water quality standard of Thachin River, the effluent charge of aquaculture in each sub-basin has to apply as the table below:

Table 5-7: The effluent charge of aqua culture in each sub-basin

Sub basin	Charge (Bath/Kg-BOD)	BOD(Kg/year)		% reduction	Cost of abatement (Bath/year)	Tax expense (Bath/year)
		Influent	Effluent			
LI	6.11	134,192.25	67,096.13	50.00%	35,725,921.78	409,776.32
RF	20.65	526,476.00	78,971.40	85.00%	142,149,911.09	1,630,459.48
LJ	6.79	297,675.75	133,954.09	55.00%	79,342,651.37	910,060.21
LK	6.79	483,168.75	217,425.94	55.00%	128,784,053.40	1,477,153.09
LL	6.79	780,351.75	351,158.29	55.00%	207,995,366.93	2,385,706.86
LM	10.20	1,400,803.84	420,241.15	70.00%	373,723,821.49	4,286,612.23
RFm	10.11	4,541,916.28	1,362,574.88	70.00%	1,200,452,084.16	13,769,185.41
LP	7.51	180,047.66	72,019.06	60.00%	47,148,390.10	540,792.03
RG	7.51	2,284,614.84	913,845.94	60.00%	598,263,338.34	6,862,080.49
LQ	61.52	52,297.66	2,614.88	95.00%	14,025,555.28	160,873.12
RH	61.52	271,069.53	13,553.48	95.00%	72,697,343.76	833,838.53
RI	4.26	3,509,936.95	2,456,955.87	30.00%	913,252,910.54	10,475,010.88
LS	3.90	888,382.63	666,286.97	25.00%	226,778,549.04	2,601,149.96
RJ	3.96	2,206,034.91	1,654,526.18	25.00%	570,641,848.39	6,545,262.00
RK	3.90	3,667,944.31	2,750,958.23	25.00%	936,320,753.84	10,739,599.05
LT	3.90	8,896.88	6,672.66	25.00%	2,271,116.46	26,049.71
LU	3.90	1,099,060.63	824,295.47	25.00%	280,558,586.84	3,218,006.99
RL	3.90	5,721,461.69	4,291,096.27	25.00%	1,460,524,714.63	16,752,218.48

Table 5-7 indicated that sub-basin LI need to reduce 50% of pollution water. The effluent should be charged at 26.51 Baht / Kg of BOD. The effluent added with cost of abatement was 905,082.31 Baht/year.

5.2.1.4 Industrial

To control and preserve the water quality standard of Thachin River, the effluent charge of industry in each sub-basin has to apply as the table below:

Table 5-8: The effluent charge of industry in each sub-basin

Sub basin	Charge (Bath/Kg-BOD)	BOD(Kg/year)		% reduction	Cost of abatement (Bath/year)	Tax expense (Bath/year)
		Influent	Effluent			
LI	0.42	26,497.78	13,248.89	50.00%	13,810.31	5,623.79
RF	2.25	130,195.50	19,529.33	85.00%	107,699.72	43,857.16
LJ	10.74	1,803.10	811.40	55.00%	21,409.36	8,718.25
RFm	1.04	3,613,003.38	1,083,901.01	70.00%	2,778,086.17	1,131,283.92
LP	2.43	157,577.80	63,031.12	60.00%	375,705.61	152,993.71
RG	1.35	1,821,384.75	728,553.90	60.00%	2,411,758.62	982,109.11
LQ	24.56	11,544.07	577.20	95.00%	34,806.81	14,173.93
RH	30.02	23,111,693.56	1,155,584.68	95.00%	85,199,692.65	34,694,763.24
RI	0.11	47,383,228.62	33,168,260.03	30.00%	8,979,717.40	3,656,693.58
LS	0.73	44,065,531.29	33,049,148.47	25.00%	59,149,200.43	24,086,559.95
RJ	0.56	4,266,169.36	3,199,627.02	25.00%	4,434,068.85	1,805,628.22
RK	1.19	1,056,674.61	792,505.96	25.00%	2,324,454.20	946,557.27
LT	0.39	47,963,547.13	35,972,660.35	25.00%	34,702,684.12	14,131,522.92
LU	0.42	21,198,491.80	15,898,868.85	25.00%	16,468,108.39	6,706,093.69
RL	0.26	38,401,885.51	28,801,414.13	25.00%	18,679,146.03	7,606,465.81

Table 5-8 indicated that sub-basin LI need to reduce 50% of pollution water. The effluent should be charged at 0.63 Baht / Kg of BOD. The effluent added with cost of abatement was 48,696.58 Baht/year.

5.3 Optimization results of Mathematical decision making model

The result of Mathematical decision-making model applied with optimization technique are shown in the table and charts below. The explanation from the table is if we want to reduce the emission (I) lower than effluent standard (reduction %) and satisfy to all constraint in model. The result from optimizing model is shown that the tax charge should be charge at rate (Baht / Unit) which lead to reduce all activities production emission (referred the Economic theory from figure 3-11). The table below show the suitable of paying tax charge and the abatement cost for all the activities however, each activity still have profit remain which is shown in the figure II. For instance, in sub-basin LI to control pollution, the production in every activities should be reduced to 50% or not excess than 170,033.80 Kg-BOD/year for whole sub-basin.

Tax charge should be applied in every activities such as pig farm, urban community, aquaculture and factory, at 0.15, 3.09, 6.11 and 0.42 Baht/Kg BOD respectively. The total expenses of all activities are the addition of Tax charge and abatement cost which are 25,167.75, 980,599.96, 36,135,879.06, and 19,374.84 Baht, respectively. From the result, the net profit of all activities in sub-basin LI are 1,733,484.25, 6,166,497.70, 99,900,748.44, and 280,376,341.99 Baht respectively which shown in the figure below. From the result of scenario 1, we have studied the pollution generating source in each sub-basin have a different tax charge. The scenario 2 show the result of applying uniform tax in each sub-basin which affect to the emission and its profit of each pollution generating sources.

The method of reducing BOD peak in each sub basin of Thachin River.

BOD emission reduction in 18 sub-basin cause the critical of water quality in middle and lower part of Thachin River Basin. By controlling the volume of effluent discharge and BOD without effect the surface water quality of Thachin River. The volume of effluent discharge is a TMDL of 7 parts in Thachin River. The information effluent discharge in sub basin is shown in table below.

Table 5-9: The main sources effluent discharge in 18 sub-basin

Sub basin has BOD higher than TMDL	Sub basin has high BOD effluent emission		BOD, TMDL has target control. (% Effluent discharge, at present)	
	Left Bank	Right Bank	Left Bank	Right Bank
Km. 190-200	LI	RF	50%	15%
Km. 160-180	LJ, LK, LL	-	45%	-
Km. 140-150	LM	RFm	30%	30%
Km. 110-120	LP	RG	100%	40%
Km. 90-100	LQ	RH	100%	5%
Km. 70-80	-	RI	-	70%
Km. 50	LS, LT, LU	RJ, RK, RL	75%	75%

Sources : PCD (2005a)

5.3.1 The method of reducing BOD peak in sub basin from Km190 to Km200 (Peak1)

Peak 1 at Km 190-200 are included Sub-basin LI and RF. In this sub basin, at present, during the dry season with rain has BOD peak which are equal to 1,222 and 9,581 kg/day respectively. Sub basin LI, the main effluent discharge has the highest ratio of BOD discharge are communities and aquatic animal farms which have a percentage of 27% and 26% respectively. Sub basin RF, the main effluent discharge has the highest ratio of BOD discharge at 14.1%, 13% and 11.2% respectively.

- *Sub-basin LI*

This sub-basin is located at KM no.180-200 from river mouth. BOD value is shown at 8.0 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 1,200 Kg-BOD/day. Urban community and aquaculture pollution sources about 42 and 44 percentage of pollution, respectively. Allowable BOD discharging load at this sub-basin is about 50 percent and target of emission reduction is 50 percent.

The table below shown that in this sub-basin, each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the non uniform tax of pig farm should be 0.15 Baht/Kg-BOD. The effluent charge of urban community should be 3.09 Baht/Kg-BOD. The effluent charge of aqua culture should be 6.11 Baht/Kg-BOD and the effluent charge of industry should be 0.42 Bath/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin Regardless of main-point sources in this sub-basin. For instance, in this sub-basin, the effluent charge is 3.80 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-10: Non-uniform tax of each main point source at sub-basin LI

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	0.15	3.09	6.11	0.42	
Influent (Kg-BOD/yr)	40,745.60	138,631.98	134,192.25	26,497.78	340,067.61
Effluent (Kg-BOD/yr)	20,152.66	69,281.29	67,066.83	13,248.89	169,749.67
Effluent Std.(Kg-BOD/yr)	20,372.80	69,315.99	67,096.13	13,248.89	170,033.80
%Reduction (Gov.)	50.00%	50.00%	50.00%	50.00%	50.00%
%Reduction (Active)	50.54%	50.03%	50.02%	50.00%	50.08%
Revenue (Baht/yr)	1,758,652.00	7,147,097.66	136,036,627.50	280,395,716.84	425,338,093.99
Cost of abatement(Baht/yr)	22,144.85	766,520.77	35,726,100.76	13,810.31	36,528,576.68
Tax expense(Baht/yr)	3,022.90	214,079.19	409,778.31	5,564.53	632,444.93
Total expense(Baht/yr)	25,167.75	980,599.96	36,135,879.06	19,374.84	37,161,021.62
Net profit(Baht/yr)	1,733,484.25	6,166,497.70	99,900,748.44	280,376,341.99	388,177,072.38
Total expense/ Revenue	1.43%	13.72%	26.56%	0.01%	8.74%

From the table above in Sub-basin LI shown that after applying tax charge for each activities which are not the same rate. Thus, the emission reduce to 50% which meet the standard limits and abatement cost is lower than the profit in pig farm, Urban community and Industry except the Aqua culture. This means the aqua culture have to pay high tax rate which can effort to run the business in this sub-basin.

Table 5-11: Uniform Tax of entire main point source at sub-basin LI

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	3.90	3.90	3.90	3.90	3.90
Influent (Kg-BOD/yr)	40,745.60	138,631.98	134,192.25	26,497.78	340,067.61
Effluent (Kg-BOD/yr)	1,146.34	57,754.09	104,537.75	2,739.66	166,177.83
Effluent Std.(Kg-BOD/yr)	20,372.80	69,315.99	67,096.13	13,248.89	170,033.80
%Reduction (Gov.)	50.00%	50.00%	50.00%	50.00%	50.00%
%Reduction (Active)	97.19%	58.34%	22.10%	89.66%	51.13%
Revenue (Baht/yr)	1,758,652.00	7,147,097.66	136,036,627.50	280,395,716.84	425,338,093.99
Cost of abatement(Baht/yr)	32,751.07	806,486.10	35,544,679.26	26,238.36	36,410,154.80
Tax expense(Baht/yr)	4,470.71	225,240.93	407,697.22	10,684.66	648,093.52
Total expense(Baht/yr)	37,221.78	1,031,727.04	35,952,376.48	36,923.02	37,058,248.32
Net profit(Baht/yr)	1,721,430.22	6,115,370.62	100,084,251.02	280,358,793.82	388,279,845.67
Total expense/ Revenue	2.12%	14.44%	26.43%	0.01%	8.71%

From the table above in Sub-basin LI shown that after applying uniform tax charge for each activities. Thus, the emission reduce to 50% which meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-12: Comparable between Non-uniform tax and Uniform tax in sub-basin LI

Sub basin LI		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		3.90	
Influent	(Kg-BOD/yr)	340,067.61	340,067.61	
Effluent	(Kg-BOD/yr)	169,749.67	166,177.83	-3,571.85
Effluent Std.	(Kg-BOD/yr)	170,033.80	170,033.80	
%Reduction	(Government)	50.00%	50.00%	
%Reduction	(Active)	50.08%	51.13%	0.01
Revenue	(Baht/yr)	425,338,093.99	425,338,093.99	
Cost of abatement	(Baht/yr)	36,528,576.68	36,410,154.80	-118,421.88
Tax expense	(Baht/yr)	632,444.93	648,093.52	15,648.59
Total expense	(Baht/yr)	37,161,021.62	37,058,248.32	-102,773.29
Net profit	(Baht/yr)	388,177,072.38	388,279,845.67	102,773.29
Totalexpense/Revenue		8.74%	8.71%	-0.02%

The main point sources in sub basin LI are Pig farm, Urban community, Aqua culture and industry.

There are 3 pig farms situated in sub basin LI, comprise of 2 middle size pig farms and 1 small size pig farm. The effluent discharge of BOD is 180 kg/day (The volume of effluent emission of pig farm is 10-20 liters/unit-day and BOD value is in between 1,500 – 3,000 mg/liter).

Urban community in sub basin LI are Phoa-Phaya District and Muang Subanburi District which have a population 3,252 and 27,887 people respectively. Urban community in LI sub basin generate BOD wastewater in the volume of 380 kg/day and none of them has been passed through the wastewater treatment system.

Aqua culture in sub-basin LI there are aqua culture cover an area approximately of 1,533 Rai. The effluent discharge of BOD is 386 kg/day or average of 0.24 kg/Rai-day (especially fish feeding with vegetable farm has the ratio of wastewater discharge approximately of 11.4 cu.m/Rai-day. The average of BOD pollutant loading is 20 mg/liter. King fresh water shrimp farm has the ratio of wastewater discharge approximately of 25.6 cu.m/Rai-day.)

Industry in sub-basin LI, there are 22 industries which generate the BOD pollutant loading approximately of 20.4 kg/day. 59% of all BOD pollutant loading come from the meat ball manufacturing. 22% and 18% of all BOD pollutant loading come from the ice cream plants and meat ball plant, respectively. The cause of these 3 type of manufactures has released high BOD pollutant loading. Due to the BOD effluent at end-of-pipe of are higher than the standard.

The method of reducing BOD peak in sub basin LI, at present, all pollutant generators which located in this sub-basin has released the wastewater. The wastewater contained total BOD pollutant loading approximately of 1,400 kg/day. After flowing and decomposing along the cannel before meet the Thachin river, the remaining BOD pollutant loading has an average of 1,222 kg/day. While Thachin river has a ability of carrying capacity at 50% of the currently situation has occurred. Hence, the target emission in this sub-basin has been set at least 50% of the capability of carrying capacity nowadays which means that BOD pollutant loading in effluent discharge might not higher than 700 kg/day.

The result of comparing Non-uniform tax and Uniform tax in sub-basin LI are using Uniform tax has less cost of abatement about 118,421.88 Baht, more tax expense about

15,648.59 Baht, less total expense about 102,773.29, and gain more net profit about 102,773.29 Baht.

- *Sub-basin RF*

This sub-basin is located at KM no.180-200 from river mouth. BOD value is shown at 8.0 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 9,600 Kg-BOD/day. Pig farm pollution sources about 56 percentage of the total pollution. Allowable BOD discharging load at this sub-basin is about 15 percent and target of emission reduction is 85 percent.

The table below shown that in this sub-basin, each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of pig farm should be 0.91 Baht/Kg-BOD. The effluent charge of urban community should be 14.96 Baht/Kg-BOD. The effluent charge of aqua culture should be 20.65 Baht/Kg-BOD and the effluent charge of industry should be 2.25 Bath/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 5.92 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-13: Non-uniform tax of each main point source at sub-basin RF

Item	**Pig farm**	**Urban community**	**Aqua culture**	**Industry**	**Sub-basin** Approve
Tax rate(Baht/Kg-BOD)	0.91	14.96	20.65	2.25	
Influent (Kg-BOD/yr)	2,084,110.76	434,537.87	526,476.00	130,195.50	3,175,320.13
Effluent (Kg-BOD/yr)	311,767.19	65,166.59	78,957.02	19,502.87	475,393.67
Effluent Std.(Kg-BOD/yr)	312,616.61	65,180.68	78,971.40	19,529.33	476,298.02
%Reduction (Gov.)	85.00%	85.00%	85.00%	85.00%	85.00%
%Reduction (Active)	85.04%	85.00%	85.00%	85.02%	85.03%
Revenue (Baht/yr)	17,527,820.00	17,594,497.74	1,018,692,885.00	195,685,864.92	1,249,501,067.66
Cost of abatement(Baht/yr)	2,078,352.19	3,490,648.00	142,150,208.02	107,759.18	147,826,967.39
Tax expense(Baht/yr)	283,708.14	974,892.14	1,630,462.46	43,881.46	2,932,944.20
Total expense(Baht/yr)	2,362,060.33	4,465,540.14	143,780,670.47	151,640.64	150,759,911.59
Net profit(Baht/yr)	15,165,759.67	13,128,957.60	874,912,214.53	195,534,224.28	1,098,741,156.07
Total expense/ Revenue	13.48%	25.38%	14.11%	0.08%	12.07%

From the table above in Sub-basin RF shown that after applying non uniform tax charge for each activities. Thus, the emission reduce to 50% which meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-14: Uniform Tax of entire main point source at sub-basin RF

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	5.92	5.92	5.92	5.92	
Influent (Kg-BOD/yr)	2,084,110.76	434,537.87	526,476.00	130,195.50	3,175,320.13
Effluent (Kg-BOD/yr)	60,011.22	134,505.24	271,541.37	9,807.04	475,864.86
Effluent Std.(Kg-BOD/yr)	312,616.61	65,180.68	78,971.40	19,529.33	476,298.02
%Reduction (Gov.)	85.00%	85.00%	85.00%	85.00%	85.00%
%Reduction (Active)	97.12%	69.05%	48.42%	92.47%	85.01%
Revenue (Baht/yr)	17,527,820.00	17,594,497.74	1,018,692,885.00	195,685,864.92	1,249,501,067.66
Cost of abatement(Baht/yr)	2,602,570.85	2,851,086.96	140,150,442.25	142,571.66	145,746,671.73
Tax expense(Baht/yr)	355,266.40	796,271.02	1,607,524.88	58,057.69	2,817,119.99
Total expense(Baht/yr)	2,957,837.25	3,647,357.98	141,757,967.13	200,629.35	148,563,791.71
Net profit(Baht/yr)	14,569,982.75	13,947,139.76	876,934,917.87	195,485,235.57	1,100,937,275.94
Total expense/ Revenue	16.88%	20.73%	13.92%	0.10%	11.89%

From the table above in Sub-basin RF shown that after applying uniform tax charge for each activities. Thus, the emission must reduce below 85% which meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-15: Comparable between Non-uniform tax and Uniform tax in sub-basin RF

Sub basin RF		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		5.92	
Influent	(Kg-BOD/yr)	3,175,320.13	3,175,320.13	
Effluent	(Kg-BOD/yr)	475,393.67	475,864.86	471.19
Effluent Std.	(Kg-BOD/yr)	476,298.02	476,298.02	
%Reduction	(Government)	85.00%	85.00%	
%Reduction	(Active)	85.03%	85.01%	0.00
Revenue	(Baht/yr)	1,249,501,067.66	1,249,501,067.66	
Cost of abatement	(Baht/yr)	147,826,967.39	145,746,671.73	-2,080,295.66
Tax expense	(Baht/yr)	2,932,944.20	2,817,119.99	-115,824.22
Total expense	(Baht/yr)	150,759,911.59	148,563,791.71	-2,196,119.87
Net profit	(Baht/yr)	1,098,741,156.07	1,100,937,275.94	2,196,119.87
Totalexpense/Revenue		12.07%	11.89%	-0.18%

The method of reducing BOD peak in sub basin RF, at present, all pollutant generators which located in this sub-basin has released the wastewater. The wastewater contained total BOD pollutant loading approximately of 11,183 kg/day. After flowing and decomposing along the cannel before meet the Thachin river, the remaining BOD pollutant loading has an average of 1,222 kg/day. While Thachin river has a ability of carrying capacity at 15% of the currently situation has occurred. Hence, the target emission in this sub-basin has been set at least 85% of the capability of carrying capacity nowadays which means that BOD pollutant loading in effluent discharge might not higher than 1,670 kg/day.

The result of comparing Non-uniform tax and Uniform tax in sub-basin LI. Uniform tax has less cost of abatement about 2,080,295.66 Baht, less tax expense about 115,824.22 Baht, less total expense about 2,196,119.87, and gain more net profit about 2,196,119.87 Baht.

5.3.2 The method of reducing BOD peak in sub basin from Km160 to Km180 (Peak2)

At sub-basin Km 160-180 are included in Sub-basin LJ , LK and LL. In this sub basin, at present, during the dry season has BOD peak at 4,324 kg/day. Sub-basin LL is the main effluent discharge which has the highest BOD discharge ratio at 50 %. Sub-basin LK and LK has the BOD discharge ratio at 30.9 % and 19.4 % respectively. In this peak 2, aqua culture as a major pollutant generator has BOD pollutant loading ratio at 98.9 %. Urban community has BOD discharge ratio at 1.1%. Industry has only one factory located which generate the small volume.

The effluent pollutant loading in cannel before meet the Thachin river has BOD pollutant loading at 3,640 kg/day. The target emission in this peak is 45% of 3 sub-basin or has the volume of BOD pollutant loading not more than 1,946 kg/day.

- *Sub-basin LJ*

This sub-basin is located at KM no.160-180 from river mouth. BOD value is shown at 6.5 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 700 Kg-BOD/day. Aquaculture pollution sources about 97 percentage of the total pollution.

Allowable BOD discharging load at this sub-basin is about 45 percent, target of emission reduction is 55 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of urban community should be 3.81 Baht/Kg-BOD. The effluent charge of aqua culture should be 6.80 Baht/Kg-BOD and the effluent charge of industry should be 10.74 Bath/Kg-BOD.

The alternative effluent charge is to set a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 6.75 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-16: Non-uniform tax of each main point source at sub-basin LJ

Item	**Urban community**	**Aqua culture**	**Industry**	**Sub-basin** Approve
Tax rate(Baht/Kg-BOD)	3.81	6.80	10.74	
Influent (Kg-BOD/yr)	8,218.34	297,675.75	1,803.10	307,697.19
Effluent (Kg-BOD/yr)	3,692.35	133,833.72	811.40	138,337.46
Effluent Std.(Kg-BOD/yr)	3,698.25	133,954.09	811.40	138,463.74
%Reduction (Gov.)	55.00%	55.00%	55.00%	55.00%
%Reduction (Active)	55.07%	55.04%	55.00%	55.04%
Revenue (Baht/yr)	397,532.78	301,767,092.50	39,866,071.18	342,030,696.46
Cost of abatement(Baht/yr)	50,370.59	79,343,469.53	21,409.36	79,415,249.48
Tax expense(Baht/yr)	14,067.87	910,069.27	8,714.38	932,851.52
Total expense(Baht/yr)	64,438.46	80,253,538.79	30,123.74	80,348,100.99
Net profit(Baht/yr)	333,094.32	221,513,553.71	39,835,947.44	261,682,595.47
Total expense/ Revenue	16.21%	26.59%	0.08%	23.49%

From the table above in Sub-basin LJ shown that after applying tax charge for each activities which are not equal. Thus, the emission reduce to 55% which meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-17: Uniform Tax of entire main point source at sub-basin LJ

Item	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	6.75	6.75	6.75	
Influent (Kg-BOD/yr)	8,218.34	297,675.75	1,803.10	307,697.19
Effluent (Kg-BOD/yr)	2,361.29	134,813.78	1,129.02	138,304.08
Effluent Std.(Kg-BOD/yr)	3,698.25	133,954.09	811.40	138,463.74
%Reduction (Gov.)	55.00%	55.00%	55.00%	55.00%
%Reduction (Active)	71.27%	54.71%	37.38%	55.05%
Revenue (Baht/yr)	397,532.78	301,767,092.50	39,866,071.18	342,030,696.46
Cost of abatement(Baht/yr)	57,069.20	79,336,829.68	18,714.59	79,412,613.48
Tax expense(Baht/yr)	15,938.70	909,992.98	7,620.89	933,552.57
Total expense(Baht/yr)	73,007.90	80,246,822.66	26,335.48	80,346,166.05
Net profit(Baht/yr)	324,524.88	221,520,269.84	39,839,735.70	261,684,530.41
Total expense/ Revenue	18.37%	26.59%	0.07%	23.49%

From the table above in Sub-basin LJ shown that after applying uniform tax charge for each activities. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-18: Comparable between Non-uniform tax and Uniform tax in sub-basin LJ

Sub basin LJ		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		6.75	
Influent	(Kg-BOD/yr)	307,697.19	307,697.19	
Effluent	(Kg-BOD/yr)	138,337.46	138,304.08	-33.38
Effluent Std.	(Kg-BOD/yr)	138,463.74	138,463.74	
%Reduction	(Government)	55.00%	55.00%	
%Reduction	(Active)	55.04%	55.05%	0.00
Revenue	(Baht/yr)	342,030,696.46	342,030,696.46	
Cost of abatement	(Baht/yr)	79,415,249.48	79,412,613.48	-2,636.00
Tax expense	(Baht/yr)	932,851.52	933,552.57	701.05
Total expense	(Baht/yr)	80,348,100.99	80,346,166.05	-1,934.95
Net profit	(Baht/yr)	261,682,595.47	261,684,530.41	1,934.95
Totalexpense/Revenue		23.49%	23.49%	0.00%

The method of reducing BOD peak in sub basin LJ can be divided into 2 choice. First is reducing 45 % equally in every main point sources. Second is reducing in each main point sources in different ratio according to the effluent ratio. According to aqua culture is the major main point source in this LJ, LL and LK sub-basin, thus the effluent pollutant loading of aqua culture is the main target for reducing BOD pollutant loading.

The result of comparing Non-uniform tax and Uniform tax in sub-basin LJ. Uniform tax has less cost of abatement about 2,636.00 Baht, higher tax expense about 701.05 Baht, less total expense about 1,934.95, and gain more net profit about 1,934.95 Baht.

- *Sub-basin LK*

This sub-basin is located at KM no.160-180 from river mouth. BOD value is shown at 6.5 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 7,100 Kg-BOD/day. Aquaculture pollution source about 99 percentage of pollution. Allowable BOD discharging load at this sub-basin is about 45 percent, target of emission reduction is 55 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of urban community should be 3.80 Baht/Kg-BOD. The effluent of aqua culture should be 6.80 Baht/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 6.77 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-19: Non-uniform tax of each main point source at sub-basin LK

Item	Urban community	Aqua culture	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	3.80	6.80	
Influent (Kg-BOD/yr)	4,900.89	483,168.75	488,069.64
Effluent (Kg-BOD/yr)	2,204.95	217,230.63	219,435.58
Effluent Std.(Kg-BOD/yr)	2,205.40	217,425.94	219,631.34
%Reduction (Gov.)	55.00%	55.00%	55.00%
%Reduction (Active)	55.01%	55.04%	55.04%
Revenue (Baht/yr)	428,977.34	489,809,562.50	490,238,539.84
Cost of abatement(Baht/yr)	30,000.75	128,785,380.92	128,815,381.66
Tax expense(Baht/yr)	8,378.82	1,477,168.26	1,485,547.08
Total expense(Baht/yr)	38,379.57	130,262,549.17	130,300,928.75
Net profit(Baht/yr)	390,597.77	359,547,013.33	359,937,611.10
Total expense/ Revenue	8.95%	26.59%	26.58%

From the table above in Sub-basin LK known that after applying non uniform tax for each activities. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-20: Uniform Tax of entire main point source at sub-basin LK

Item	Urban community	Aqua culture	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	6.77	6.77	
Influent (Kg-BOD/yr)	4,900.89	483,168.75	488,069.64
Effluent (Kg-BOD/yr)	1,403.94	218,182.21	219,586.15
Effluent Std.(Kg-BOD/yr)	2,205.40	217,425.94	219,631.34
%Reduction (Gov.)	55.00%	55.00%	55.00%
%Reduction (Active)	71.35%	54.84%	55.01%
Revenue (Baht/yr)	428,977.34	489,809,562.50	490,238,539.84
Cost of abatement(Baht/yr)	34,031.93	128,778,924.44	128,812,956.37
Tax expense(Baht/yr)	9,504.67	1,477,093.56	1,486,598.23
Total expense(Baht/yr)	43,536.60	130,256,018.00	130,299,554.60
Net profit(Baht/yr)	385,440.74	359,553,544.50	359,938,985.24
Total expense/ Revenue	10.15%	26.59%	26.58%

From the table above in Sub-basin LK shown that after applying uniform tax charge for each activities. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-21: Comparable between Non-uniform tax and Uniform tax in sub-basin LK

Sub basin LK		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		6.77	
Influent	(Kg-BOD/yr)	488,069.64	488,069.64	
Effluent	(Kg-BOD/yr)	219,435.58	219,586.15	150.57
Effluent Std.	(Kg-BOD/yr)	219,631.34	219,631.34	
%Reduction	(Government)	55.00%	55.00%	
%Reduction	(Active)	55.04%	55.01%	0.00
Revenue	(Baht/yr)	490,238,539.84	490,238,539.84	
Cost of abatement	(Baht/yr)	128,815,381.66	128,812,956.37	-2,425.29
Tax expense	(Baht/yr)	1,485,547.08	1,486,598.23	1,051.15
Total expense	(Baht/yr)	130,300,928.75	130,299,554.60	-1,374.14
Net profit	(Baht/yr)	359,937,611.10	359,938,985.24	1,374.14
Totalexpense/Revenue		26.58%	26.58%	0.00%

The method of reducing BOD peak in sub basin LK can be divided into 2 choice. First is reducing 45 % equally in every main point sources. Second is reducing in each main point sources in different ratio according to the effluent ratio. According to aqua culture is the major main point source in this LJ, LL and LK sub-basin, thus the effluent pollutant loading of aqua culture is the main target for reducing BOD pollutant loading.

The result of comparing Non-uniform tax and Uniform tax in sub-basin LK. Uniform tax has less cost of abatement about 2,425.29 Baht, higher tax expense about 1,051.15Baht, less total expense about 1,374.14 Baht, and gain more net profit about 1,374.14 Baht.

- *Sub-basin LL*

This sub-basin is located at KM no.160-180 from river mouth. BOD value is shown at 6.5 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 1,800 Kg-BOD/day. Aquaculture pollution sources about 99 percentage of pollution. Allowable BOD discharging load at this sub-basin is about 45 percent, target of emission reduction is 55 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of urban community should be 3.80 Baht/Kg-BOD and the effluent of aqua culture should be 6.80 Baht/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 6.78 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-22: Non-uniform tax of each main point source at sub-basin LL

Item	**Urban community**	**Aqua culture**	**Sub-basin** Approve
Tax rate(Baht/Kg-BOD)	3.80	6.80	
Influent (Kg-BOD/yr)	5,244.30	780,351.75	785,596.05
Effluent (Kg-BOD/yr)	2,359.66	350,842.77	353,202.43
Effluent Std.(Kg-BOD/yr)	2,359.93	351,158.29	353,518.22
%Reduction (Gov.)	55.00%	55.00%	55.00%
%Reduction (Active)	55.01%	55.04%	55.04%
Revenue (Baht/yr)	1,340,137.55	791,077,132.50	792,417,270.05
Cost of abatement(Baht/yr)	32,105.65	207,997,511.48	208,029,617.13
Tax expense(Baht/yr)	8,966.72	2,385,730.83	2,394,697.55
Total expense(Baht/yr)	41,072.37	210,383,242.31	210,424,314.68
Net profit(Baht/yr)	1,299,065.18	580,693,890.19	581,992,955.37
Total expense/ Revenue	3.06%	26.59%	26.55%

From the table above in Sub-basin LL known that after applying tax charge for each activities. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-23: Uniform Tax of entire main point source at sub-basin LL

Item	Urban community	Aqua culture	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	6.78	6.78	
Influent (Kg-BOD/yr)	5,244.30	780,351.75	785,596.05
Effluent (Kg-BOD/yr)	1,500.71	351,865.87	353,366.59
Effluent Std.(Kg-BOD/yr)	2,359.93	351,158.29	353,518.22
%Reduction (Gov.)	55.00%	55.00%	55.00%
%Reduction (Active)	71.38%	54.91%	55.02%
Revenue (Baht/yr)	1,340,137.55	791,077,132.50	792,417,270.05
Cost of abatement(Baht/yr)	36,431.42	207,990,564.60	208,026,996.02
Tax expense(Baht/yr)	10,174.83	2,385,650.63	2,395,825.45
Total expense(Baht/yr)	46,606.25	210,376,215.23	210,422,821.48
Net profit(Baht/yr)	1,293,531.30	580,700,917.27	581,994,448.57
Total expense/ Revenue	3.48%	26.59%	26.55%

From the table above in Sub-basin LL shown that after applying uniform tax for each activities. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-24: Comparable between Non-uniform tax and Uniform tax in sub-basin LL

Sub basin LL		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		6.78	
Influent	(Kg-BOD/yr)	785,596.05	785,596.05	
Effluent	(Kg-BOD/yr)	353,202.43	353,366.59	164.15
Effluent Std.	(Kg-BOD/yr)	353,518.22	353,518.22	
%Reduction	(Government)	55.00%	55.00%	
%Reduction	(Active)	55.04%	55.02%	0.00
Revenue	(Baht/yr)	792,417,270.05	792,417,270.05	
Cost of abatement	(Baht/yr)	208,029,617.13	208,026,996.02	-2,621.10
Tax expense	(Baht/yr)	2,394,697.55	2,395,825.45	1,127.90
Total expense	(Baht/yr)	210,424,314.68	210,422,821.48	-1,493.20
Net profit	(Baht/yr)	581,992,955.37	581,994,448.57	1,493.20
Totalexpense/Revenue		26.55%	26.55%	0.00%

The method of reducing BOD peak in sub basin LL can be divided into 2 choice. First is reducing 45 % equally in every main point sources. Second is reducing in each main point sources in different ratio according to the effluent ratio. According to aqua culture is the major main point source in this LJ, LL and LK sub-basin, thus the effluent pollutant loading of aqua culture is the main target for reducing BOD pollutant loading.

The result of comparing Non-uniform tax and Uniform tax in sub-basin LL. Uniform tax has less cost of abatement about 2,621.10 Baht, higher tax expense about 1,127.90 Baht, less total expense about 1,493.20 Baht, and gain more net profit about 1,493.20 Baht.

5.3.3 The method of reducing BOD peak in sub basin from Km140 to Km150 (Peak3)

At sub-basin Km 140-150 are included in Sub-basin LM and RFm. In this sub basin, at present, during the dry season has BOD peak at 19,109 kg/day. Sub-basin RFm is the main effluent emission which has the highest BOD discharge ratio at 79 %.

The main point source in this Peak 3 are Aquatic animal farm and pig farm which has BOD pollutant loading in the ratio at 82% and 14.2 % respectively. The target emission in this peak is 30% or has the volume of BOD pollutant loading not more than 5,732 kg/day.

- *Sub-basin RFm*

This sub-basin is located at KM no.140-160 from river mouth. BOD value is shown at 6.5 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 12,000 Kg-BOD/day. Aquaculture and pig farm pollution sources about 81 and 14 percentage of pollution, respectively. Allowable BOD discharging load at this sub-basin is about 30 percent, target of emission reduction is 70 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of Pig farm should be 0.38 Baht/Kg-BOD, the effluent charge of urban community should be 6.42 Baht/Kg-BOD and the effluent of aqua culture should be 10.11 Baht/Kg-BOD and the effluent charge of industry should be 1.05 Baht/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 5.73 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-25: Non-uniform tax of each main point source at sub-basin RFm

Item	**Pig farm**	**Urban community**	**Aqua culture**	**Industry**	**Sub-basin** Approve
Tax rate(Baht/Kg-BOD)	0.38	6.42	10.11	1.05	
Influent (Kg-BOD/yr)	988,869.60	146,743.26	4,541,916.28	3,613,003.38	9,290,532.52
Effluent (Kg-BOD/yr)	292,070.65	44,008.68	1,361,943.80	1,079,286.00	2,777,309.13
Effluent Std.(Kg-BOD/yr)	296,660.88	44,022.98	1,362,574.88	1,083,901.01	2,787,159.76
%Reduction (Gov.)	70.00%	70.00%	70.00%	70.00%	70.00%
%Reduction (Active)	70.46%	70.01%	70.01%	70.13%	70.11%
Revenue (Baht/yr)	42,681,357.00	11,173,465.48	7,688,317,305.00	5,798,532,010.43	13,540,704,137.91
Cost of abatement(Baht/yr)	813,051.11	1,011,631.32	1,200,458,462.98	2,782,917.41	1,205,066,062.82
Tax expense(Baht/yr)	110,986.85	282,535.73	13,769,251.77	1,133,250.30	15,296,024.65
Total expense(Baht/yr)	924,037.95	1,294,167.06	1,214,227,714.75	3,916,167.71	1,220,362,087.47
Net profit(Baht/yr)	41,757,319.05	9,879,298.42	6,474,089,590.25	5,794,615,842.72	12,320,342,050.44
Total expense/ Revenue	2.16%	11.58%	15.79%	0.07%	9.01%

From the Figure above in Sub-basin RFm known that after applying tax charge for each activities which are not equal. Thus, the emission reduce to 70% which meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-26: Uniform Tax of entire main point source at sub-basin RFm

Item	**Pig farm**	**Urban community**	**Aqua culture**	**Industry**	**Sub-basin** Approve
Tax rate(Baht/Kg-BOD)	5.73	5.73	5.73	5.73	
Influent (Kg-BOD/yr)	988,869.60	146,743.26	4,541,916.28	3,613,003.38	9,290,532.52
Effluent (Kg-BOD/yr)	26,831.71	48,099.20	2,387,587.86	323,171.18	2,785,689.95
Effluent Std.(Kg-BOD/yr)	296,660.88	44,022.98	1,362,574.88	1,083,901.01	2,787,159.76
%Reduction (Gov.)	70.00%	70.00%	70.00%	70.00%	70.00%
%Reduction (Active)	97.29%	67.22%	47.43%	91.06%	70.02%
Revenue (Baht/yr)	42,681,357.00	11,173,465.48	7,688,317,305.00	5,798,532,010.43	13,540,704,137.91
Cost of abatement(Baht/yr)	1,126,296.33	986,829.07	1,192,753,637.32	4,547,382.19	1,199,414,144.90
Tax expense(Baht/yr)	153,745.70	275,608.41	13,680,878.44	1,851,770.86	15,962,003.41
Total expense(Baht/yr)	1,280,042.02	1,262,437.48	1,206,434,515.76	6,399,153.05	1,215,376,148.31
Net profit(Baht/yr)	41,401,314.98	9,911,028.00	6,481,882,789.24	5,792,132,857.38	12,325,327,989.60
Total expense/ Revenue	3.00%	11.30%	15.69%	0.11%	8.98%

From the table above in Sub-basin RFm shown that after applying uniform tax charge for each activities. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-27: Comparable between Non-uniform tax and Uniform tax in sub-basin RFm

Sub basin RFm		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		5.73	
Influent	(Kg-BOD/yr)	9,290,532.52	9,290,532.52	
Effluent	(Kg-BOD/yr)	2,777,309.13	2,785,689.95	8,380.82
Effluent Std.	(Kg-BOD/yr)	2,787,159.76	2,787,159.76	
%Reduction	(Government)	70.00%	70.00%	
%Reduction	(Active)	70.11%	70.02%	0.00
Revenue	(Baht/yr)	13,540,704,137.91	13,540,704,137.91	
Cost of abatement	(Baht/yr)	1,205,066,062.82	1,199,414,144.90	-5,651,917.92
Tax expense	(Baht/yr)	15,296,024.65	15,962,003.41	665,978.76
Total expense	(Baht/yr)	1,220,362,087.47	1,215,376,148.31	-4,985,939.16
Net profit	(Baht/yr)	12,320,342,050.44	12,325,327,989.60	4,985,939.16
Totalexpense/Revenue		9.01%	8.98%	-0.04%

The method of reducing BOD peak in sub basin RFm can be divided into 2 choices. First is reducing 30 % equally in every main point sources. Second is reducing in each main point sources in different ratio according to the effluent ratio.

The result of comparing Non-uniform tax and Uniform tax in sub-basin RFm. Uniform tax has less cost of abatement about 5,651,917.92 Baht, higher tax expense about 665,978.76 Baht, less total expense about 4,985,939.16 Baht, and gain more net profit about 4,985,939.16 Baht.

- *Sub-basin LM*

This sub-basin is located at KM no.140-160 from river mouth. BOD value is shown at 6.5 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 3,000 Kg-BOD/day. Aquaculture pollution sources about 99 percentage of pollution. Allowable BOD discharging load at this sub-basin is about 30 percent, target of emission reduction is 70 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example the effluent charge of aqua culture should be 10.21 Baht/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 10.21 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-28: Non-uniform tax of each main point source at sub-basin LM

Item	Aqua culture	Subbasin Approve
Tax rate(Baht/Kg-BOD)	10.21	
Influent (Kg-BOD/yr)	1,400,803.84	1,400,803.84
Effluent (Kg-BOD/yr)	419,848.99	419,848.99
Effluent Std.(Kg-BOD/yr)	420,241.15	420,241.15
%Reduction (Gov.)	70.00%	70.00%
%Reduction (Active)	70.03%	70.03%
Revenue (Baht/yr)	1,408,819,957.50	1,408,819,957.50
Cost of abatement(Baht/yr)	373,727,823.56	373,727,823.56
Tax expense(Baht/yr)	4,286,658.21	4,286,658.21
Total expense(Baht/yr)	378,014,481.78	378,014,481.78
Net profit(Baht/yr)	1,030,805,475.72	1,030,805,475.72
Total expense/ Revenue	26.83%	26.83%

From the table above in Sub-basin LM known that after applying tax charge for each activities which are not equal. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-29: Uniform Tax of entire main point source at sub-basin LM

Item	Aqua culture	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	10.21	
Influent (Kg-BOD/yr)	1,400,803.84	1,400,803.84
Effluent (Kg-BOD/yr)	419,848.94	419,848.94
Effluent Std.(Kg-BOD/yr)	420,241.15	420,241.15
%Reduction (Gov.)	70.00%	70.00%
%Reduction (Active)	70.03%	70.03%
Revenue (Baht/yr)	1,408,819,957.50	1,408,819,957.50
Cost of abatement(Baht/yr)	373,727,824.07	373,727,824.07
Tax expense(Baht/yr)	4,286,657.70	4,286,657.70
Total expense(Baht/yr)	378,014,481.78	378,014,481.78
Net profit(Baht/yr)	1,030,805,475.72	1,030,805,475.72
Total expense/ Revenue	26.83%	26.83%

From the table above in Sub-basin LM shown that after applying uniform tax charge for each activities at the same rate. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities. The sub-basin LM profit of using Uniform tax and Non-uniform tax are the same.

Table 5-30: Comparable between Non-uniform tax and Uniform tax in sub-basin LM

Sub basin LM		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		10.21	
Influent	(Kg-BOD/yr)	1,400,803.84	1,400,803.84	
Effluent	(Kg-BOD/yr)	419,848.99	419,848.94	-0.05
Effluent Std.	(Kg-BOD/yr)	420,241.15	420,241.15	
%Reduction	(Government)	70.00%	70.00%	
%Reduction	(Active)	70.03%	70.03%	0.00
Revenue	(Baht/yr)	1,408,819,957.50	1,408,819,957.50	
Cost of abatement	(Baht/yr)	373,727,823.56	373,727,824.07	0.51
Tax expense	(Baht/yr)	4,286,658.21	4,286,657.70	-0.51
Total expense	(Baht/yr)	378,014,481.78	378,014,481.78	0.00
Net profit	(Baht/yr)	1,030,805,475.72	1,030,805,475.72	0.00
Totalexpense/Revenue		26.83%	26.83%	0.00%

The method of reducing BOD peak in sub basin LM can be divided into 2 choices. First is reducing 30 % equally in every main point sources. Second is reducing in each main point sources in different ratio according to the effluent ratio.

The result of comparing Non-uniform tax and Uniform tax in sub-basin LM. Uniform tax has more cost of abatement about 0.51Baht, less tax expense about 0.51 Baht, non total expense about 0.00 Baht, and no net profit about 0.00 Baht.

5.3.4 The method of reducing BOD peak in sub basin from Km110 to Km120 (Peak4)

At sub-basin Km 110-120 are included in Sub-basin RG and LP. In this sub basin, at present, during the dry season has BOD peak at 12,790 kg/day. Sub-basin RG is the main effluent emission which has the highest BOD discharge ratio at 95 %.

The main point source in this Peak 4 are Aquatic animal farm and pig farm which has BOD pollutant loading ratio at 52.8 % and 42.6 % respectively. The rest main point sources are urban community and industry which has BOD pollutant loading ration at 3.5 % and 1.1% respectively.

Due to the sub-basin LP has an effluent emission ration at 5 %. Thus, only sub-basin RG has to reduce the effluent emission. The target emission of sub-basin RG is 40% or has the volume of BOD pollutant loading not more than 5,116 kg/day.

- *Sub-basin LP*

This sub-basin is located at KM no.110-120 from river mouth. BOD value is shown at 4.8 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 570 Kg-BOD/day. Aquaculture pollution sources about 75 percentage of pollution.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of Pig farm should be 0.19 Baht/Kg-BOD, the effluent charge of urban community should be 4.43 Baht/Kg-BOD and the effluent of aqua culture should be 7.51 Baht/Kg-BOD and the effluent charge of industry should be 2.43 Baht/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 4.93 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-31: Non-uniform tax of each main point source at sub-basin LP

Item	Pig farm	Urban community	Aqua culture	Industry	Subbasin Approve
Tax rate(Baht/Kg-BOD)	0.19	4.43	7.51	2.43	
Influent (Kg-BOD/yr)	31,481.25	17,969.04	180,047.66	157,577.80	387,075.74
Effluent (Kg-BOD/yr)	12,259.02	7,182.80	72,009.74	62,980.73	154,432.29
Effluent Std.(Kg-BOD/yr)	12,592.50	7,187.61	72,019.06	63,031.12	154,830.30
%Reduction (Gov.)	60.00%	60.00%	60.00%	60.00%	60.00%
%Reduction (Active)	61.06%	60.03%	60.01%	60.03%	60.10%
Revenue (Baht/yr)	1,350,100.00	2,643,154.95	175,221,392.50	5,798,532,010.43	5,977,746,657.88
Cost of abatement(Baht/yr)	17,063.16	113,932.29	47,148,460.07	375,828.00	47,655,283.52
Tax expense(Baht/yr)	2,329.21	31,819.79	540,793.18	153,043.17	727,985.35
Total expense(Baht/yr)	19,392.37	145,752.08	47,689,253.26	528,871.17	48,383,268.87
Net profit(Baht/yr)	1,330,707.63	2,497,402.87	127,532,139.24	5,798,003,139.26	5,929,363,389.01
Total expense/ Revenue	1.44%	5.51%	27.22%	0.01%	0.81%

From the table above in Sub-basin LP known that after applying non-uniform tax for each activities which are not equal. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-32: Uniform Tax of entire main point source at sub-basin LP

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	4.93	4.93	4.93	4.93	
Influent (Kg-BOD/yr)	31,481.25	17,969.04	180,047.66	157,577.80	387,075.74
Effluent (Kg-BOD/yr)	698.57	6,606.72	109,171.90	38,095.73	154,572.92
Effluent Std.(Kg-BOD/yr)	12,592.50	7,187.61	72,019.06	63,031.12	154,830.30
%Reduction (Gov.)	60.00%	60.00%	60.00%	60.00%	60.00%
%Reduction (Active)	97.78%	63.23%	39.36%	75.82%	60.07%
Revenue (Baht/yr)	1,350,100.00	2,643,154.95	175,221,392.50	5,798,532,010.43	5,977,746,657.88
Cost of abatement(Baht/yr)	25,229.37	116,623.76	46,923,960.32	461,208.58	47,527,022.03
Tax expense(Baht/yr)	3,443.95	32,571.14	538,217.48	187,811.95	762,044.52
Total expense(Baht/yr)	28,673.32	149,194.90	47,462,177.80	649,020.53	48,289,066.55
Net profit(Baht/yr)	1,321,426.68	2,493,960.05	127,759,214.70	5,797,882,989.90	5,929,457,591.33
Total expense/ Revenue	2.12%	5.64%	27.09%	0.01%	0.81%

From the table above in Sub-basin LP shown that after applying uniform tax for each activities. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-33: Comparable between Non-uniform tax and Uniform tax in sub-basin LP

Sub basin LP		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		4.93	
Influent	(Kg-BOD/yr)	387,075.74	387,075.74	
Effluent	(Kg-BOD/yr)	154,432.29	154,572.92	140.64
Effluent Std.	(Kg-BOD/yr)	154,830.30	154,830.30	
%Reduction	(Government)	60.00%	60.00%	
%Reduction	(Active)	60.10%	60.07%	0.00
Revenue	(Baht/yr)	5,977,746,657.88	5,977,746,657.88	
Cost of abatement	(Baht/yr)	47,655,283.52	47,527,022.03	-128,261.49
Tax expense	(Baht/yr)	727,985.35	762,044.52	34,059.16
Total expense	(Baht/yr)	48,383,268.87	48,289,066.55	-94,202.33
Net profit	(Baht/yr)	5,929,363,389.01	5,929,457,591.33	94,202.33
Totalexpense/Revenue		0.81%	0.81%	0.00%

The result of comparing Non-uniform tax and Uniform tax in sub-basin LP. Uniform tax has less cost of abatement about 128,261.49 Baht, higher tax expense about 34,059.16 Baht, less total expense about 94,202.33 Baht, and gain more net profit about 94,202.33 Baht.

- *Sub-basin RG*

This sub-basin is located at KM no.110-120 from river mouth. BOD value is shown at 4.8 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 8,400 Kg-BOD/day. Aquaculture and pig farm pollute about 58 and 38 percentage of pollution, respectively.. Allowable BOD discharging load at this sub-basin is about 40 percent, target of emission reduction is 60 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of Pig farm should be 0.30 Baht/Kg-BOD, the effluent charge of urban community should be 4.44 Baht/Kg-BOD and the effluent of aqua culture should be 7.51 Baht/Kg-BOD and the effluent charge of industry should be 1.35 Baht/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 3.46 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-34: Non-uniform tax of each main point source at sub-basin RG

Item	**Pig farm**	**Urban community**	**Aqua culture**	**Industry**	**Sub-basin** Approve
Tax rate(Baht/Kg-BOD)	0.30	4.44	7.51	1.35	
Influent (Kg-BOD/yr)	1,985,859.15	31,648.20	2,284,614.84	1,821,384.75	6,123,506.95
Effluent (Kg-BOD/yr)	773,438.04	12,637.65	913,726.70	727,796.25	2,427,598.63
Effluent Std.(Kg-BOD/yr)	794,343.66	12,659.28	913,845.94	728,553.90	2,449,402.78
%Reduction (Gov.)	60.00%	60.00%	60.00%	60.00%	60.00%
%Reduction (Active)	61.05%	60.07%	60.01%	60.04%	60.36%
Revenue (Baht/yr)	85,861,664.00	3,613,478.47	2,223,374,647.50	4,837,476,701.55	7,150,326,491.52
Cost of abatement(Baht/yr)	1,699,788.51	200,908.75	598,264,233.78	2,412,780.70	602,577,711.74
Tax expense(Baht/yr)	232,031.41	56,111.17	6,862,087.49	982,524.94	8,132,755.01
Total expense(Baht/yr)	1,931,819.92	257,019.92	605,126,321.27	3,395,305.63	610,710,466.75
Net profit(Baht/yr)	83,929,844.08	3,356,458.55	1,618,248,326.23	4,834,081,395.91	6,539,616,024.77
Total expense/ Revenue	2.25%	7.11%	27.22%	0.07%	8.54%

From the table above in Sub-basin RG known that after applying tax charge for each activities which are not equal. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-35: Uniform Tax of entire main point source at sub-basin RG

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	3.46	3.46	3.46	3.46	
Influent (Kg-BOD/yr)	1,985,859.15	31,648.20	2,284,614.84	1,821,384.75	6,123,506.95
Effluent (Kg-BOD/yr)	89,954.35	15,357.95	1,965,909.69	372,862.08	2,444,084.07
Effluent Std.(Kg-BOD/yr)	794,343.66	12,659.28	913,845.94	728,553.90	2,449,402.78
%Reduction (Gov.)	60.00%	60.00%	60.00%	60.00%	60.00%
%Reduction (Active)	95.47%	51.47%	13.95%	79.53%	60.09%
Revenue (Baht/yr)	85,861,664.00	3,613,478.47	2,223,374,647.50	4,837,476,701.55	7,150,326,491.52
Cost of abatement(Baht/yr)	2,280,061.46	190,262.18	593,029,679.45	3,168,099.04	598,668,102.13
Tax expense(Baht/yr)	311,242.05	53,138.52	6,802,047.52	1,290,102.79	8,456,530.88
Total expense(Baht/yr)	2,591,303.51	243,400.70	599,831,726.97	4,458,201.83	607,124,633.01
Net profit(Baht/yr)	83,270,360.49	3,370,077.78	1,623,542,920.53	4,833,018,499.72	6,543,201,858.51
Total expense/ Revenue	3.02%	6.74%	26.98%	0.09%	8.49%

From the table above in Sub-basin RG shown that after applying uniform tax charge for each activities. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-36: Comparable between Non-uniform tax and Uniform tax in sub-basin RG

Sub basin RG		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		3.46	
Influent	(Kg-BOD/yr)	6,123,506.95	6,123,506.95	
Effluent	(Kg-BOD/yr)	2,427,598.63	2,444,084.07	16,485.44
Effluent Std.	(Kg-BOD/yr)	2,449,402.78	2,449,402.78	
%Reduction	(Government)	60.00%	60.00%	
%Reduction	(Active)	60.36%	60.09%	0.00
Revenue	(Baht/yr)	7,150,326,491.52	7,150,326,491.52	
Cost of abatement	(Baht/yr)	602,577,711.74	598,668,102.13	-3,909,609.62
Tax expense	(Baht/yr)	8,132,755.01	8,456,530.88	323,775.87
Total expense	(Baht/yr)	610,710,466.75	607,124,633.01	-3,585,833.74
Net profit	(Baht/yr)	6,539,616,024.77	6,543,201,858.51	3,585,833.74
Totalexpense/Revenue		8.54%	8.49%	-0.05%

The method of reducing BOD peak in sub basin RG can be divided into 2 choices. First is reducing 60 % equally in every main point sources. Second is reducing in each main point sources in different ratio which can be divided into 2 sub-case. In 2.1 is appointed the deduction ratio in each main point source according to the effluent discharge ratio. In 2.2, the reduction of effluent emission ration in each main point sources according to the ease of reduction BOD pollutant loading.

The result of comparing Non-uniform tax and Uniform tax in sub-basin RG. Uniform tax has less cost of abatement about 3,909,609.62 Baht, higher tax expense about 323,775.87 Baht, less total expense about 3,585,833.74 Baht, and gain more net profit about 3,585,833.74 Baht.

<u>5.3.5 The method of reducing BOD peak in sub basin from Km90 to Km100 (Peak5)</u>

At sub-basin Km 90-100 are included in Sub-basin LQ and RH. In this sub basin, at present, during the dry season has BOD peak at 17,921 kg/day.

The main point source in this Peak 5 are Pig farm and industry which has BOD pollutant loading ratio at 55.4 % and 24.9 % respectively. The rest main point sources are urban community and aqua culture which has BOD pollutant loading ratio at 14.7 % and 4.9% respectively.

Due to the sub-basin LQ has an small volume of effluent emission at 2.3 %. Thus, only sub-basin RH has to reduce the effluent emission. The target emission of sub-basin RH is 95% or has the volume of BOD pollutant loading not more than 880 kg/day.

- *<u>Sub-basin LQ</u>*

This sub-basin is located at KM no.90-100 from river mouth. BOD value is shown at 6.7 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 360 Kg-BOD/day. Aquaculture and pig farm pollution sources about 40 and 35 percentage of pollution, respectively.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of Pig farm should be 2.16 Baht/Kg-BOD, the effluent charge of urban community should be 63.37 Baht/Kg-BOD and the effluent of aqua culture should be 61.53 Baht/Kg-BOD and the effluent charge of industry should be 24.56 Baht/Kg-BOD.

The alternative effluent charge is a uniform tax charge which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 33.06 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-37: Non-uniform tax of each main point source at sub-basin LQ

Item	**Pig farm**	**Urban community**	**Aqua culture**	**Industry**	**Sub-basin** Approve
Tax rate(Baht/Kg-BOD)	2.16	63.37	61.53	24.56	
Influent (Kg-BOD/yr)	73,682.55	37,395.92	52,297.66	11,544.07	174,920.20
Effluent (Kg-BOD/yr)	3,683.84	1,869.72	2,614.55	577.14	8,745.25
Effluent Std.(Kg-BOD/yr)	3,684.13	1,869.80	2,614.88	577.20	8,746.01
%Reduction (Gov.)	95.00%	95.00%	95.00%	95.00%	95.00%
%Reduction (Active)	95.00%	95.00%	95.00%	95.00%	95.00%
Revenue (Baht/yr)	3,111,100.00	1,490,507.05	50,895,792.50	420,964,440.92	476,461,840.47
Cost of abatement(Baht/yr)	58,291.08	424,239.35	14,025,575.75	34,808.38	14,542,914.56
Tax expense(Baht/yr)	7,957.10	118,484.46	160,873.27	14,174.55	301,489.37
Total expense(Baht/yr)	66,248.18	542,723.81	14,186,449.01	48,982.93	14,844,403.93
Net profit(Baht/yr)	3,044,851.82	947,783.24	36,709,343.49	420,915,457.98	461,617,436.54
Total expense/ Revenue	2.13%	36.41%	27.87%	0.01%	3.12%

From the table above in Sub-basin LQ known that after applying tax charge for each activities which are not equal. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-38: Uniform Tax of entire main point source at sub-basin LQ

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	33.05	33.05	33.05	33.05	33.05
Influent (Kg-BOD/yr)	73,682.55	37,395.92	52,297.66	11,544.07	174,920.20
Effluent (Kg-BOD/yr)	334.10	3,110.07	4,833.39	467.36	8,744.92
Effluent Std.(Kg-BOD/yr)	3,684.13	1,869.80	2,614.88	577.20	8,746.01
%Reduction (Gov.)	95.00%	95.00%	95.00%	95.00%	95.00%
%Reduction (Active)	99.55%	91.68%	90.76%	95.95%	95.00%
Revenue (Baht/yr)	3,111,100.00	2,033,230.86	50,895,792.50	420,964,440.92	477,004,564.28
Cost of abatement(Baht/yr)	80,890.76	368,036.35	13,927,073.72	37,931.23	14,413,932.06
Tax expense(Baht/yr)	11,042.08	102,787.74	159,743.48	15,446.25	289,019.54
Total expense(Baht/yr)	91,932.83	470,824.08	14,086,817.20	53,377.48	14,702,951.59
Net profit(Baht/yr)	3,019,167.17	1,562,406.77	36,808,975.30	420,911,063.44	462,301,612.68
Total expense/ Revenue	2.95%	23.16%	27.68%	0.01%	3.08%

From the table above in Sub-basin LQ shown that after applying uniform tax for each activities. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-39: Comparable between Non-uniform tax and Uniform tax in sub-basin LQ

Sub basin LQ		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		33.05	
Influent	(Kg-BOD/yr)	174,920.20	174,920.20	
Effluent	(Kg-BOD/yr)	8,745.25	8,744.92	-0.34
Effluent Std.	(Kg-BOD/yr)	8,746.01	8,746.01	
%Reduction	(Government)	95.00%	95.00%	
%Reduction	(Active)	95.00%	95.00%	0.00
Revenue	(Baht/yr)	476,461,840.47	477,004,564.28	
Cost of abatement	(Baht/yr)	14,542,914.56	14,413,932.06	-128,982.50
Tax expense	(Baht/yr)	301,489.37	289,019.54	-12,469.84
Total expense	(Baht/yr)	14,844,403.93	14,702,951.59	-141,452.34
Net profit	(Baht/yr)	461,617,436.54	462,301,612.68	684,176.15
Totalexpense/Revenue		3.12%	3.08%	-0.03%

The result of comparing Non-uniform tax and Uniform tax in sub-basin LQ. Uniform tax has less cost of abatement about 128,982.50 Baht, less tax expense about 12,469.84 Baht, less total expense about 141,452.34 Baht, and gain more net profit about 684,176.15 Baht.

- *Sub-basin RH*

This sub-basin is located at KM no.90-100 from river mouth. BOD value is shown at 6.7 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 12,000 Kg-BOD/day. Pig farm pollution sources about 54 percentage of pollution. Allowable BOD discharging load at this sub-basin is about 5 percent, target of emission reduction is 95 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of Pig farm should be 3.33 Baht/Kg-BOD, the effluent charge of urban community should be 43.99 Baht/Kg-BOD and the effluent of aqua culture should be 61.53 Baht/Kg-BOD and the effluent charge of industry should be 30.03 Baht/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 27.79 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-40: Non-uniform tax of each main point source at sub-basin RH

Item	**Pig farm**	**Urban community**	**Aqua culture**	**Industry**	**Sub-basin** Approve
Tax rate(Baht/Kg-BOD)	3.33	43.99	61.53	30.03	
Influent (Kg-BOD/yr)	3,458,866.84	2,981,167.04	271,069.53	23,111,693.56	29,822,796.97
Effluent (Kg-BOD/yr)	172,943.34	149,055.78	13,551.74	1,155,409.98	1,490,960.85
Effluent Std.(Kg-BOD/yr)	172,943.34	149,058.35	13,553.48	1,155,584.68	1,491,139.85
%Reduction (Gov.)	95.00%	95.00%	95.00%	95.00%	95.00%
%Reduction (Active)	95.00%	95.00%	95.00%	95.00%	95.00%
Revenue (Baht/yr)	160,103,663.00	38,923,016.43	263,803,382.50	29,533,795,936.75	29,996,625,998.68
Cost of abatement(Baht/yr)	4,223,481.10	23,477,529.85	72,697,450.36	85,204,938.12	185,603,399.43
Tax expense(Baht/yr)	575,901.33	6,556,963.64	833,838.81	34,696,961.85	42,663,665.62
Total expense(Baht/yr)	4,799,382.42	30,034,493.49	73,531,289.17	119,901,899.96	228,267,065.05
Net profit(Baht/yr)	155,304,280.58	8,888,522.94	190,272,093.33	29,413,894,036.79	29,768,358,933.64
Total expense/ Revenue	3.00%	77.16%	27.87%	0.41%	0.76%

From the Figure above in Sub-basin RH known that after applying tax charge for each activities which are not equal. Thus, the emission reduce to 95% which meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-41: Uniform Tax of entire main point source at sub-basin RH

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	27.79	27.79	27.79	27.79	
Influent (Kg-BOD/yr)	3,458,866.84	2,981,167.04	271,069.53	23,111,693.56	29,822,796.97
Effluent (Kg-BOD/yr)	26,763.99	213,436.21	29,735.78	1,220,842.72	1,490,778.70
Effluent Std.(Kg-BOD/yr)	172,943.34	149,058.35	13,553.48	1,155,584.68	1,491,139.85
%Reduction (Gov.)	95.00%	95.00%	95.00%	95.00%	95.00%
%Reduction (Active)	99.23%	92.84%	89.03%	94.72%	95.00%
Revenue (Baht/yr)	160,103,663.00	38,923,016.43	263,803,382.50	29,533,795,936.75	29,996,625,998.68
Cost of abatement(Baht/yr)	5,448,645.95	21,237,635.90	72,045,133.56	83,314,898.29	182,046,313.70
Tax expense(Baht/yr)	743,771.42	5,931,392.30	826,357.27	33,927,219.13	41,428,740.11
Total expense(Baht/yr)	6,192,417.37	27,169,028.20	72,871,490.82	117,242,117.42	223,475,053.81
Net profit(Baht/yr)	153,911,245.63	11,753,988.23	190,931,891.68	29,416,553,819.33	29,773,150,944.87
Total expense/ Revenue	3.87%	69.80%	27.62%	0.40%	0.75%

From the table above in Sub-basin RH shown that after applying uniform tax charge for each activities at the same rate. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-42: Comparable between Non-uniform tax and Uniform tax in sub-basin RH

Sub basin RH		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		27.79	
Influent	(Kg-BOD/yr)	29,822,796.97	29,822,796.97	
Effluent	(Kg-BOD/yr)	1,490,960.85	1,490,778.70	-182.15
Effluent Std.	(Kg-BOD/yr)	1,491,139.85	1,491,139.85	
%Reduction	(Government)	95.00%	95.00%	
%Reduction	(Active)	95.00%	95.00%	0.00
Revenue	(Baht/yr)	29,996,625,998.68	29,996,625,998.68	
Cost of abatement	(Baht/yr)	185,603,399.43	182,046,313.70	-3,557,085.72
Tax expense	(Baht/yr)	42,663,665.62	41,428,740.11	-1,234,925.51
Total expense	(Baht/yr)	228,267,065.05	223,475,053.81	-4,792,011.24
Net profit	(Baht/yr)	29,768,358,933.64	29,773,150,944.87	4,792,011.24
Totalexpense/Revenue		0.76%	0.75%	-0.02%

The result of comparing Non-uniform tax and Uniform tax in sub-basin RH. Uniform tax has less cost of abatement about 3,557,085.72 Baht, less tax expense about 1,234,925.51Baht, less total expense about 4,792,011.24 Baht, and gain more net profit about 4,792,011.24 Baht.

5.3.6 The method of reducing BOD peak in sub basin from Km 70 to Km 80 (Peak6)

Sub-basin located at Km 70- 80 are included in Sub-basin RI. In this sub basin, at present, during the dry season has BOD peak at 14,421 kg/day.

The main point source in this Peak 6 are Aquatic animal farm, Pig farm, industry and urban community which have BOD pollutant loading ratio at 66.7 %, 15.4 %, 12.4 % and 5.5 % respectively.

The target emission in this peak6 is 30% or has the volume of BOD pollutant loading not more than 10,100 kg/day.

- *Sub-basin RI*

This sub-basin is located at KM no.70-90 from river mouth. BOD value is shown at 6.0 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 11,000 Kg-BOD/day. Aquaculture pollution sources about 68 percentage of pollution. Allowable BOD discharging load at this sub-basin is about 70 percent, target of emission reduction is 30 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of Pig farm should be 0.15 Baht/Kg-BOD, the effluent charge of urban community should be 0.12 Baht/Kg-BOD and the effluent of aqua culture should be 4.27 Baht/Kg-BOD and the effluent charge of industry should be 0.10 Baht/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 0.12 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-43: Non-uniform tax of each main point source at sub-basin RI

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	0.15	2.13	4.27	0.12	
Influent (Kg-BOD/yr)	823,831.46	716,956.59	3,509,936.95	47,383,228.62	52,433,953.62
Effluent (Kg-BOD/yr)	550,828.19	500,429.00	2,453,207.25	31,229,257.71	34,733,722.14
Effluent Std.(Kg-BOD/yr)	576,682.02	501,869.62	2,456,955.87	33,168,260.03	36,703,767.54
%Reduction (Gov.)	30.00%	30.00%	30.00%	30.00%	30.00%
%Reduction (Active)	33.14%	30.20%	30.11%	34.09%	33.76%
Revenue (Baht/yr)	37,103,683.00	45,407,952.86	3,415,851,410.25	54,158,796,949.23	57,657,159,995.35
Cost of abatement(Baht/yr)	605,284.26	3,816,552.78	913,268,904.78	9,202,713.13	926,893,454.95
Tax expense(Baht/yr)	82,624.23	1,065,913.76	10,475,194.96	3,747,510.92	15,371,243.87
Total expense(Baht/yr)	687,908.49	4,882,466.54	923,744,099.74	12,950,224.06	942,264,698.83
Net profit(Baht/yr)	36,415,774.51	40,525,486.32	2,492,107,310.51	54,145,846,725.18	56,714,895,296.52
Total expense/ Revenue	1.85%	10.75%	27.04%	0.02%	1.63%

From the Figure above in Sub-basin RI known that after applying tax charge for each activities which are not equal. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-44: Uniform Tax of entire main point source at sub-basin RI

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	0.12	0.12	0.12	0.12	
Influent (Kg-BOD/yr)	823,831.46	716,956.59	3,509,936.95	47,383,228.62	52,433,953.62
Effluent (Kg-BOD/yr)	670,340.00	716,956.59	3,509,936.95	31,229,194.16	36,126,427.70
Effluent Std.(Kg-BOD/yr)	576,682.02	501,869.62	2,456,955.87	33,168,260.03	36,703,767.54
%Reduction (Gov.)	30.00%	30.00%	30.00%	30.00%	30.00%
%Reduction (Active)	18.63%	0.00%	0.00%	34.09%	31.10%
Revenue (Baht/yr)	37,103,683.00	45,407,952.86	3,415,851,410.25	54,158,796,949.23	57,657,159,995.35
Cost of abatement(Baht/yr)	589,275.37	-	-	9,202,720.76	9,791,996.13
Tax expense(Baht/yr)	80,440.80	86,034.79	421,192.43	3,747,503.30	4,335,171.32
Total expense(Baht/yr)	669,716.17	86,034.79	421,192.43	12,950,224.06	14,127,167.45
Net profit(Baht/yr)	36,433,966.83	45,321,918.07	3,415,430,217.82	54,145,846,725.18	57,643,032,827.89
Total expense/ Revenue	1.80%	0.19%	0.01%	0.02%	0.02%

From the Figure above in Sub-basin RI shown that after applying uniform tax charge for each activities at the same rate. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities. The sub-basin RH profit of using Uniform tax is greater than using Non-uniform tax approximately of 928,137,531.37 Baht / year.

Table 5-45: Comparable between Non-uniform tax and Uniform tax in sub-basin RI

Sub basin RI		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		0.12	
Influent	(Kg-BOD/yr)	52,433,953.62	52,433,953.62	
Effluent	(Kg-BOD/yr)	34,733,722.14	36,126,427.70	1,392,705.56
Effluent Std.	(Kg-BOD/yr)	36,703,767.54	36,703,767.54	
%Reduction	(Government)	30.00%	30.00%	
%Reduction	(Active)	33.76%	31.10%	-0.03
Revenue	(Baht/yr)	57,657,159,995.35	57,657,159,995.35	
Cost of abatement	(Baht/yr)	926,893,454.95	9,791,996.13	-917,101,458.82
Tax expense	(Baht/yr)	15,371,243.87	4,335,171.32	-11,036,072.55
Total expense	(Baht/yr)	942,264,698.83	14,127,167.45	-928,137,531.37
Net profit	(Baht/yr)	56,714,895,296.52	57,643,032,827.89	928,137,531.37
Totalexpense/Revenue		1.63%	0.02%	-1.61%

The result of comparing Non-uniform tax and Uniform tax in sub-basin LQ. Uniform tax has less cost of abatement about 917,101,458.82 Baht, less tax expense about 11,036,072.55 Baht, less total expense about 928,137,531.37 Baht, and gain more net profit about 928,137,531.37 Baht.

<u>5.3.7 The method of reducing BOD peak in sub basin from river mouth to Km 50 (Peak7)</u>

At sub-basin Km 0 - 50 are included in Sub-basin LS, LT, LU, RJ, RK and RL. In this sub basin, at present, during the dry season has BOD peak at 56,802 kg/day.

The main sub-basins have high effluent emission are sub-basin RL, LS, RK, RJ, LU and LT which has BOD pollutant loading ratio at 32.6 %, 20.3 %, 17.5 %, 12.9 %, 11.1 % and 5.6 %

The main point source in this Peak 7 are aquatic animal farm, industry, urban community and pig farm which have BOD pollutant loading ratio at 62.3 %, 25.2 %, 8.9 % and 3.6 % respectively.

The target emission in this peak6 is 25% or has the volume of BOD pollutant loading not more than 44,870 kg/day.

- *Sub-basin LS*

This sub-basin is located at KM no.40-50 from river mouth. BOD value is shown at 6.5 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 9,800 Kg-BOD/day. Industry pollution sources about 44 percentage of pollution. Allowable BOD discharging load at this sub-basin is about 75 percent, target of emission reduction is 25 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of Pig farm should be 0.13 Baht/Kg-BOD, the effluent charge of urban community should be 1.92 Baht/Kg-BOD and the effluent of aqua culture should be 3.91 Baht/Kg-BOD and the effluent charge of industry should be 0.73 Baht/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 0.74 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-46: Non-uniform tax of each main point source at sub-basin LS

Item	**Pig farm**	**Urban community**	**Aqua culture**	**Industry**	**Sub-basin** Approve
Tax rate(Baht/Kg-BOD)	0.13	1.92	3.91	0.73	
Influent (Kg-BOD/yr)	685,541.18	594,845.01	888,382.63	44,065,531.29	46,234,300.10
Effluent (Kg-BOD/yr)	514,155.88	445,059.71	665,268.02	33,010,848.67	34,635,332.28
Effluent Std.(Kg-BOD/yr)	514,155.88	446,133.76	666,286.97	33,049,148.47	34,675,725.07
%Reduction (Gov.)	25.00%	25.00%	25.00%	25.00%	25.00%
%Reduction (Active)	25.00%	25.18%	25.11%	25.09%	25.09%
Revenue (Baht/yr)	30,656,075.00	20,862,973.86	831,316,445.00	306,197,737,724.28	307,080,573,218.14
Cost of abatement(Baht/yr)	509,815.52	3,059,630.42	226,782,530.06	59,177,136.50	289,529,112.50
Tax expense(Baht/yr)	66,840.26	854,514.64	2,601,197.94	24,097,919.53	27,620,472.37
Total expense(Baht/yr)	576,655.79	3,914,145.05	229,383,728.00	83,275,056.03	317,149,584.87
Net profit(Baht/yr)	30,079,419.21	16,948,828.81	601,932,717.00	306,114,462,668.25	306,763,423,633.27
Total expense/ Revenue	1.88%	18.76%	27.59%	0.03%	0.10%

From the Figure above in Sub-basin LS known that after applying tax charge for each activities which are not equal. Thus, the emission reduce to 25.09% which meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-47: Uniform Tax of entire main point source at sub-basin LS

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	0.74	0.74	0.74	0.74	
Influent (Kg-BOD/yr)	685,541.18	594,845.01	888,382.63	44,065,531.29	46,234,300.10
Effluent (Kg-BOD/yr)	115,389.36	594,845.01	888,382.63	32,692,751.25	34,291,368.25
Effluent Std.(Kg-BOD/yr)	514,155.88	446,133.76	666,286.97	33,049,148.47	34,675,725.07
%Reduction (Gov.)	25.00%	25.00%	25.00%	25.00%	25.00%
%Reduction (Active)	83.17%	0.00%	0.00%	25.81%	25.83%
Revenue (Baht/yr)	30,656,075.00	20,862,973.86	831,316,445.00	306,197,737,724.28	307,080,573,218.14
Cost of abatement(Baht/yr)	625,166.59	-	-	59,410,934.46	60,036,101.05
Tax expense(Baht/yr)	85,388.13	440,185.31	657,403.14	24,192,635.93	25,375,612.50
Total expense(Baht/yr)	710,554.72	440,185.31	657,403.14	83,603,570.39	85,411,713.56
Net profit(Baht/yr)	29,945,520.28	20,422,788.55	830,659,041.86	306,114,134,153.89	306,995,161,504.59
Total expense/ Revenue	2.32%	2.11%	0.08%	0.03%	0.03%

From the Figure above in Sub-basin LS shown that after applying uniform tax charge for each activities at the same rate. Thus, the emission reduce to 25.83% which meet the standard limits and abatement cost is lower than the profit in every activities. The sub-basin LS profit of using Uniform tax is greater than using Non-uniform tax approximately of 231,737,871.32 Baht / year.

Table 5-48: Comparable between Non-uniform tax and Uniform tax in sub-basin LS

Sub basin LS		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		0.74	
Influent	(Kg-BOD/yr)	46,234,300.10	46,234,300.10	
Effluent	(Kg-BOD/yr)	34,635,332.28	34,291,368.25	-343,964.03
Effluent Std.	(Kg-BOD/yr)	34,675,725.07	34,675,725.07	
%Reduction	(Government)	25.00%	25.00%	
%Reduction	(Active)	25.09%	25.83%	0.01
Revenue	(Baht/yr)	307,080,573,218.14	307,080,573,218.14	
Cost of abatement	(Baht/yr)	289,529,112.50	60,036,101.05	-229,493,011.44
Tax expense	(Baht/yr)	27,620,472.37	25,375,612.50	-2,244,859.87
Total expense	(Baht/yr)	317,149,584.87	85,411,713.56	-231,737,871.31
Net profit	(Baht/yr)	306,763,423,633.27	306,995,161,504.59	231,737,871.31
Totalexpense/Revenue		0.10%	0.03%	-0.08%

The result of comparing Non-uniform tax and Uniform tax in sub-basin LS. Uniform tax has less cost of abatement about 229,493,011.44 Baht, less tax expense about 2,244,859.87 Baht, less total expense about 231,737,871.31 Baht, and gain more net profit about 231,737,871.31 Baht.

- *Sub-basin RJ*

This sub-basin is located at KM no.40-50 from river mouth. BOD value is shown at 6.5 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 5,800 Kg-BOD/day. Aquaculture pollution sources about 75 percentage of pollution. Allowable BOD discharging load at this sub-basin is about 75 percent, target of emission reduction is 25 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of Pig farm should be 0.11 Baht/Kg-BOD, the effluent charge of urban community should be 1.86 Baht/Kg-BOD and the effluent of aqua culture should be 3.96 Baht/Kg-BOD and the effluent charge of industry should be 0.57 Baht/Kg-BOD.

The alternative effluent charge is to set a single effluent charge which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 0.74 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-49: Non-uniform tax of each main point source at sub-basin RJ

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	0.11	1.86	3.96	0.57	
Influent (Kg-BOD/yr)	83,636.10	196,757.15	2,206,034.91	4,266,169.36	6,752,597.52
Effluent (Kg-BOD/yr)	59,843.05	147,567.86	1,652,862.84	3,176,952.42	5,037,226.18
Effluent Std.(Kg-BOD/yr)	62,727.08	147,567.86	1,654,526.18	3,199,627.02	5,064,448.14
%Reduction (Gov.)	25.00%	25.00%	25.00%	25.00%	25.00%
%Reduction (Active)	28.45%	25.00%	25.08%	25.53%	25.40%
Revenue (Baht/yr)	3,665,228.00	12,961,700.77	2,123,747,660.00	23,654,889,434.85	25,795,264,023.62
Cost of abatement(Baht/yr)	48,221.65	984,669.23	570,648,431.85	4,446,928.85	576,128,251.58
Tax expense(Baht/yr)	6,582.74	274,476.22	6,545,336.86	1,810,862.88	8,637,258.70
Total expense(Baht/yr)	54,804.39	1,259,145.45	577,193,768.71	6,257,791.73	584,765,510.28
Net profit(Baht/yr)	3,610,423.61	11,702,555.32	1,546,553,891.29	23,648,631,643.12	25,210,498,513.34
Total expense/ Revenue	1.50%	9.71%	27.18%	0.03%	2.27%

From the table above in Sub-basin RJ known that after applying tax charge for each activities which are not equal. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-50: Uniform Tax of entire main point source at sub-basin RJ

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	0.74	0.74	0.74	0.74	
Influent (Kg-BOD/yr)	83,636.10	196,757.15	2,206,034.91	4,266,169.36	6,752,597.52
Effluent (Kg-BOD/yr)	11,184.43	196,757.15	2,206,034.91	2,639,125.11	5,053,101.60
Effluent Std.(Kg-BOD/yr)	62,727.08	147,567.86	1,654,526.18	3,199,627.02	5,064,448.14
%Reduction (Gov.)	25.00%	25.00%	25.00%	25.00%	25.00%
%Reduction (Active)	86.63%	0.00%	0.00%	38.14%	25.17%
Revenue (Baht/yr)	3,665,228.00	12,961,700.77	2,123,747,660.00	23,654,889,434.85	25,795,264,023.62
Cost of abatement(Baht/yr)	60,627.97	-	-	4,795,808.23	4,856,436.20
Tax expense(Baht/yr)	8,276.48	145,600.29	1,632,465.83	1,952,952.58	3,739,295.18
Total expense(Baht/yr)	68,904.45	145,600.29	1,632,465.83	6,748,760.81	8,595,731.38
Net profit(Baht/yr)	3,596,323.55	12,816,100.48	2,122,115,194.17	23,648,140,674.04	25,786,668,292.24
Total expense/ Revenue	1.88%	1.12%	0.08%	0.03%	0.03%

From the Figure above in Sub-basin RJ shown that after applying uniform tax charge for each activities. Thus, the emission reduce which meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-51: Comparable between Non-uniform tax and Uniform tax in sub-basin RJ

Sub basin RJ		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		0.74	
Influent	(Kg-BOD/yr)	6,752,597.52	6,752,597.52	
Effluent	(Kg-BOD/yr)	5,037,226.18	5,053,101.60	15,875.42
Effluent Std.	(Kg-BOD/yr)	5,064,448.14	5,064,448.14	
%Reduction	(Government)	25.00%	25.00%	
%Reduction	(Active)	25.40%	25.17%	0.00
Revenue	(Baht/yr)	25,795,264,023.62	25,795,264,023.62	
Cost of abatement	(Baht/yr)	576,128,251.58	4,856,436.20	-571,271,815.38
Tax expense	(Baht/yr)	8,637,258.70	3,739,295.18	-4,897,963.51
Total expense	(Baht/yr)	584,765,510.28	8,595,731.38	-576,169,778.90
Net profit	(Baht/yr)	25,210,498,513.34	25,786,668,292.24	576,169,778.90
Totalexpense/Revenue		2.27%	0.03%	-2.23%

The result of comparing Non-uniform tax and Uniform tax in sub-basin RJ. Uniform tax has less cost of abatement about 571,271,815.38 Baht, less tax expense about 4,897,963.51 Baht, less total expense about 576,169,778.90 Baht, and gain more net profit about 576,169,778.90 Baht.

- <u>*Sub-basin RK*</u>

This sub-basin is located at KM no.20-40 from river mouth. BOD value is shown at 6.2 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 8,200 Kg-BOD/day. Aquaculture pollution sources about 97 percentage of pollution. Allowable BOD discharging load at this sub-basin is about 75 percent, target of emission reduction is 25 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of Pig farm should be 0.09 Baht/Kg-BOD, the effluent charge of urban community should be 1.99 Baht/Kg-BOD and the effluent of aqua culture should be 3.91 Baht/Kg-BOD and the effluent charge of industry should be 1.20 Baht/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 0.74 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-52: Non-uniform tax of each main point source at sub-basin RK

Item	**Pig farm**	**Urban community**	**Aqua culture**	**Industry**	**Sub-basin** Approve
Tax rate(Baht/Kg-BOD)	0.09	1.99	3.91	1.20	
Influent (Kg-BOD/yr)	12,590.60	133,711.88	3,667,944.31	1,056,674.61	4,870,921.40
Effluent (Kg-BOD/yr)	9,442.95	100,173.19	2,746,875.51	789,987.84	3,646,479.49
Effluent Std.(Kg-BOD/yr)	9,442.95	100,283.91	2,750,958.23	792,505.96	3,653,191.05
%Reduction (Gov.)	25.00%	25.00%	25.00%	25.00%	25.00%
%Reduction (Active)	25.00%	25.08%	25.11%	25.24%	25.14%
Revenue (Baht/yr)	569,390.00	8,427,918.52	3,432,330,102.50	2,400,331,773.75	5,841,659,184.77
Cost of abatement(Baht/yr)	6,235.48	713,712.34	936,336,704.56	2,327,468.54	939,384,120.92
Tax expense(Baht/yr)	849.87	199,344.65	10,740,283.24	947,985.41	11,888,463.16
Total expense(Baht/yr)	7,085.35	913,056.99	947,076,987.80	3,275,453.95	951,272,584.09
Net profit(Baht/yr)	562,304.65	7,514,861.54	2,485,253,114.70	2,397,056,319.79	4,890,386,600.68
Total expense/ Revenue	1.24%	10.83%	27.59%	0.14%	16.28%

From the table above in Sub-basin RK known that after applying tax charge for each activities which are not equal. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-53: Uniform Tax of entire main point source at sub-basin RK

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	3.35	3.35	3.35	3.35	3.35
Influent (Kg-BOD/yr)	12,590.60	133,711.88	3,667,944.31	1,056,674.61	4,870,921.40
Effluent (Kg-BOD/yr)	392.31	66,667.89	3,200,290.68	380,815.00	3,648,165.89
Effluent Std.(Kg-BOD/yr)	9,442.95	100,283.91	2,750,958.23	792,505.96	3,653,191.05
%Reduction (Gov.)	25.00%	25.00%	25.00%	25.00%	25.00%
%Reduction (Active)	96.88%	50.14%	12.75%	63.96%	25.10%
Revenue (Baht/yr)	569,390.00	8,427,918.52	3,432,330,102.50	2,400,331,773.75	5,841,659,184.77
Cost of abatement(Baht/yr)	9,626.09	799,670.10	934,697,343.71	3,132,805.82	938,639,445.71
Tax expense(Baht/yr)	1,314.24	223,337.45	10,720,973.78	1,275,730.26	12,221,355.72
Total expense(Baht/yr)	10,940.33	1,023,007.54	945,418,317.49	4,408,536.07	950,860,801.43
Net profit(Baht/yr)	558,449.67	7,404,910.98	2,486,911,785.01	2,395,923,237.67	4,890,798,383.33
Total expense/ Revenue	1.92%	12.14%	27.54%	0.18%	16.28%

From the table above in Sub-basin RK shown that after applying uniform tax charge for each activities. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-54: Comparable between Non-uniform tax and Uniform tax in sub-basin RK

Sub basin RK		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		3.35	
Influent	(Kg-BOD/yr)	4,870,921.40	4,870,921.40	
Effluent	(Kg-BOD/yr)	3,646,479.49	3,648,165.89	1,686.40
Effluent Std.	(Kg-BOD/yr)	3,653,191.05	3,653,191.05	
%Reduction	(Government)	25.00%	25.00%	
%Reduction	(Active)	25.14%	25.10%	0.00
Revenue	(Baht/yr)	5,841,659,184.77	5,841,659,184.77	
Cost of abatement	(Baht/yr)	939,384,120.92	938,639,445.71	-744,675.21
Tax expense	(Baht/yr)	11,888,463.16	12,221,355.72	332,892.56
Total expense	(Baht/yr)	951,272,584.09	950,860,801.43	-411,782.65
Net profit	(Baht/yr)	4,890,386,600.68	4,890,798,383.33	411,782.65
Totalexpense/Revenue		16.28%	16.28%	-0.01%

The result of comparing Non-uniform tax and Uniform tax in sub-basin RK. Uniform tax has less cost of abatement about 744,675.21 Baht, more tax expense about 332,892.56 Baht, less total expense about 411,782.65 Baht, and gain more net profit about 411,782.65 Baht.

- *Sub-basin LT*

This sub-basin is located at KM no.0-20 from river mouth. BOD value is shown at 7.0 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 3,000 Kg-BOD/day. Industry pollution sources about 89 percentage of pollution. Allowable BOD discharging load at this sub-basin is about 75 percent, target of emission reduction is 25 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of urban community should be 1.88 Baht/Kg-BOD and the effluent of aqua culture should be 3.91 Baht/Kg-BOD and the effluent charge of industry should be 0.40 Baht/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 0.40 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-55: Non-uniform tax of each main point source at sub-basin LT

Item	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	1.88	3.91	0.40	
Influent (Kg-BOD/yr)	55,468.22	8,896.88	47,963,547.13	48,027,912.22
Effluent (Kg-BOD/yr)	41,543.98	6,662.47	35,513,930.23	35,562,136.68
Effluent Std.(Kg-BOD/yr)	41,601.16	6,672.66	35,972,660.35	36,020,934.17
%Reduction (Gov.)	25.00%	25.00%	25.00%	25.00%
%Reduction (Active)	25.10%	25.11%	25.96%	25.96%
Revenue (Baht/yr)	13,227,414.33	8,325,375.00	69,844,138,681.56	69,865,691,470.89
Cost of abatement(Baht/yr)	279,650.55	2,271,156.26	34,884,525.61	37,435,332.42
Tax expense(Baht/yr)	78,102.69	26,050.26	14,205,572.09	14,309,725.04
Total expense(Baht/yr)	357,753.24	2,297,206.52	49,090,097.70	51,745,057.46
Net profit(Baht/yr)	12,869,661.09	6,028,168.48	69,795,048,583.86	69,813,946,413.43
Total expense/ Revenue	2.70%	27.59%	0.07%	0.07%

From the table above in Sub-basin LT known that after applying tax charge for each activities which are not equal. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-56: Uniform Tax of entire main point source at sub-basin LT

Item	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	0.40	0.40	0.40	
Influent (Kg-BOD/yr)	55,468.22	8,896.88	47,963,547.13	48,027,912.22
Effluent (Kg-BOD/yr)	55,468.22	8,896.88	35,513,932.09	35,578,297.18
Effluent Std.(Kg-BOD/yr)	41,601.16	6,672.66	35,972,660.35	36,020,934.17
%Reduction (Gov.)	25.00%	25.00%	25.00%	25.00%
%Reduction (Active)	0.00%	0.00%	25.96%	25.92%
Revenue (Baht/yr)	13,227,414.33	8,325,375.00	69,844,138,681.56	69,865,691,470.89
Cost of abatement(Baht/yr)	-	-	34,884,524.86	34,884,524.86
Tax expense(Baht/yr)	22,187.29	3,558.75	14,205,572.83	14,231,318.87
Total expense(Baht/yr)	22,187.29	3,558.75	49,090,097.70	49,115,843.74
Net profit(Baht/yr)	13,205,227.04	8,321,816.25	69,795,048,583.86	69,816,575,627.16
Total expense/ Revenue	0.17%	0.04%	0.07%	0.07%

From the table above in Sub-basin LT shown that after applying uniform tax charge for each activities. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-57: Comparable between Non-uniform tax and Uniform tax in sub-basin LT

Sub basin LT		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		0.40	
Influent	(Kg-BOD/yr)	48,027,912.22	48,027,912.22	
Effluent	(Kg-BOD/yr)	35,562,136.68	35,578,297.18	16,160.50
Effluent Std.	(Kg-BOD/yr)	36,020,934.17	36,020,934.17	
%Reduction	(Government)	25.00%	25.00%	
%Reduction	(Active)	25.96%	25.92%	0.00
Revenue	(Baht/yr)	69,865,691,470.89	69,865,691,470.89	
Cost of abatement	(Baht/yr)	37,435,332.42	34,884,524.86	-2,550,807.55
Tax expense	(Baht/yr)	14,309,725.04	14,231,318.87	-78,406.17
Total expense	(Baht/yr)	51,745,057.46	49,115,843.74	-2,629,213.72
Net profit	(Baht/yr)	69,813,946,413.43	69,816,575,627.16	2,629,213.72
Totalexpense/Revenue		0.07%	0.07%	0.00%

The result of comparing Non-uniform tax and Uniform tax in sub-basin LT. Uniform tax has less cost of abatement about 2,550,807.55 Baht, less tax expense about 78,406.17 Baht, less total expense about 2,629,213.72 Baht, and gain more net profit about 2,629,213.72 Baht.

- *Sub-basin LU*

This sub-basin is located at KM no.0-20 from river mouth. BOD value of is shown at 7.0 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 5,800 Kg-BOD/day. Aquaculture and industry pollute about 99 and 34 percentage of pollution, respectively. Allowable BOD discharging load at this sub-basin is about 75 percent, target of emission reduction is 25 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of urban community should be 1.84 Baht/Kg-BOD and the effluent of aqua culture should be 3.91 Baht/Kg-BOD and the effluent charge of industry should be 0.43 Baht/Kg-BOD.

The alternative effluent charge is a uniform tax which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 0.44 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-58: Non-uniform tax of each main point source at sub-basin LU

Item	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	1.84	3.91	0.43	
Influent (Kg-BOD/yr)	588,827.67	1,099,060.63	21,198,491.80	22,886,380.09
Effluent (Kg-BOD/yr)	440,469.09	823,034.03	15,682,731.26	16,946,234.38
Effluent Std.(Kg-BOD/yr)	441,620.75	824,295.47	15,898,868.85	17,164,785.07
%Reduction (Gov.)	25.00%	25.00%	25.00%	25.00%
%Reduction (Active)	25.20%	25.11%	26.02%	25.95%
Revenue (Baht/yr)	12,316,254.12	7,020,455,722.50	31,575,430,891.57	38,608,202,868.19
Cost of abatement(Baht/yr)	2,901,901.44	280,563,515.23	16,560,156.21	300,025,572.87
Tax expense(Baht/yr)	810,463.13	3,218,063.07	6,743,574.44	10,772,100.65
Total expense(Baht/yr)	3,712,364.57	283,781,578.30	23,303,730.65	310,797,673.52
Net profit(Baht/yr)	8,603,889.55	6,736,674,144.20	31,552,127,160.92	38,297,405,194.67
Total expense/ Revenue	30.14%	4.04%	0.07%	0.81%

From the table above in Sub-basin LU known that after applying tax charge for each activities which are not equal. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-59: Uniform Tax of entire main point source at sub-basin LU

Item	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	0.44	0.44	0.44	
Influent (Kg-BOD/yr)	588,827.67	1,099,060.63	21,198,491.80	22,886,380.09
Effluent (Kg-BOD/yr)	588,827.67	1,099,060.63	15,428,611.24	17,116,499.53
Effluent Std.(Kg-BOD/yr)	441,620.75	824,295.47	15,898,868.85	17,164,785.07
%Reduction (Gov.)	25.00%	25.00%	25.00%	25.00%
%Reduction (Active)	0.00%	0.00%	27.22%	25.21%
Revenue (Baht/yr)	12,316,254.12	7,020,455,722.50	31,575,430,891.57	38,608,202,868.19
Cost of abatement(Baht/yr)	-	-	16,670,690.11	16,670,690.11
Tax expense(Baht/yr)	259,084.17	483,586.68	6,788,588.94	7,531,259.79
Total expense(Baht/yr)	259,084.17	483,586.68	23,459,279.05	24,201,949.90
Net profit(Baht/yr)	12,057,169.95	7,019,972,135.83	31,551,971,612.52	38,584,000,918.29
Total expense/ Revenue	2.10%	0.01%	0.07%	0.06%

From the table above in Sub-basin LU shown that after applying uniform tax charge for each activities at the same rate. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-60: Comparable between Non-uniform tax and Uniform tax in sub-basin LU

Sub basin LU		Non-uniform(X)	Uniform(X-alpha)	Different(alpha)
Tax rate	(Baht/KgBOD)		0.44	
Influent	(Kg-BOD/yr)	22,886,380.09	22,886,380.09	
Effluent	(Kg-BOD/yr)	16,946,234.38	17,116,499.53	170,265.14
Effluent Std.	(Kg-BOD/yr)	17,164,785.07	17,164,785.07	
%Reduction	(Government)	25.00%	25.00%	
%Reduction	(Active)	25.95%	25.21%	-0.01
Revenue	(Baht/yr)	38,608,202,868.19	38,608,202,868.19	
Cost of abatement	(Baht/yr)	300,025,572.87	16,670,690.11	-283,354,882.77
Tax expense	(Baht/yr)	10,772,100.65	7,531,259.79	-3,240,840.85
Total expense	(Baht/yr)	310,797,673.52	24,201,949.90	-286,595,723.62
Net profit	(Baht/yr)	38,297,405,194.67	38,584,000,918.29	286,595,723.62
Totalexpense/Revenue		0.81%	0.06%	-0.74%

The result of comparing Non-uniform tax and Uniform tax in sub-basin LU. Uniform tax has less cost of abatement about 283,354,882.77 Baht, less tax expense about 3,240,840.85 Baht, less total expense about 286,595,723.62 Baht, and gain more net profit about 286,595,723.62 Baht.

- *Sub-basin RL*

This sub-basin is located at KM no.0-20 from river mouth. BOD value of is shown at 7.0 mg/l and BOD loading from pollution generating sources that flowed to Thachin River is about 14,500 Kg-BOD/day. Aquaculture pollution sources about 78 percentage of pollution. Allowable BOD discharging load at this sub-basin is about 75 percent, target of emission reduction is 25 percent.

The table below shown that in this sub-basin, In each main-point sources has a different effluent charge according to the number of each main-point sources and the quantity of pollution water has been generated. Hence, the effluent charges for each main-point source should not the same. For example, the effluent charge of Pig farm should be 0.10 Baht/Kg-BOD, the effluent charge of urban community should be 1.90 Baht/Kg-BOD and the effluent of aqua culture should be 3.91 Baht/Kg-BOD and the effluent charge of industry should be 0.27 Baht/Kg-BOD.

The alternative effluent charge is to set a single effluent charge which is a single effluent charge for all main-point sources in this sub-basin. Thus, regardless of main-point sources in this sub-basin will be charged at the same rate. For instance, in this sub-basin, the effluent charge is 0.29 Baht/Kg-BOD to all main-point sources in this sub-basin.

Table 5-61: Non-uniform tax of each main point source at sub-basin RL

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	0.10	1.90	3.91	0.27	
Influent (Kg-BOD/yr)	1,642.50	132,415.02	5,721,461.69	38,401,885.51	44,257,404.72
Effluent (Kg-BOD/yr)	1,180.72	99,001.05	4,284,528.24	28,352,790.12	32,737,500.14
Effluent Std.(Kg-BOD/yr)	1,231.88	99,311.27	4,291,096.27	28,801,414.13	33,193,053.54
%Reduction (Gov.)	25.00%	25.00%	25.00%	25.00%	25.00%
%Reduction (Active)	28.11%	25.23%	25.11%	26.17%	26.03%
Revenue (Baht/yr)	88,050.00	20,179,296.57	6,049,383,982.50	64,926,053,871.63	70,995,705,200.70
Cost of abatement(Baht/yr)	863.42	673,508.10	1,460,550,375.71	18,798,942.80	1,480,023,690.04
Tax expense(Baht/yr)	118.07	188,102.00	16,752,505.44	7,655,253.33	24,595,978.84
Total expense(Baht/yr)	981.49	861,610.10	1,477,302,881.15	26,454,196.14	1,504,619,668.88
Net profit(Baht/yr)	87,068.51	19,317,686.46	4,572,081,101.35	64,899,599,675.49	69,491,085,531.82
Total expense/ Revenue	1.11%	4.27%	24.42%	0.04%	2.12%

From the table above in Sub-basin RL known that after applying tax charge for each activities which are not equal. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-62: Uniform Tax of entire main point source at sub-basin RL

Item	Pig farm	Urban community	Aqua culture	Industry	Sub-basin Approve
Tax rate(Baht/Kg-BOD)	0.29	0.29	0.29	0.29	
Influent (Kg-BOD/yr)	1,642.50	132,415.02	5,721,461.69	38,401,885.51	44,257,404.72
Effluent (Kg-BOD/yr)	475.33	132,415.02	5,721,461.69	26,948,962.02	32,803,314.06
Effluent Std.(Kg-BOD/yr)	1,231.88	99,311.27	4,291,096.27	28,801,414.13	33,193,053.54
%Reduction (Gov.)	25.00%	25.00%	25.00%	25.00%	25.00%
%Reduction (Active)	71.06%	0.00%	0.00%	29.82%	25.88%
Revenue (Baht/yr)	88,050.00	20,179,296.57	6,049,383,982.50	64,926,053,871.63	70,995,705,200.70
Cost of abatement(Baht/yr)	977.60	-	-	19,191,728.57	19,192,706.17
Tax expense(Baht/yr)	137.85	38,400.36	1,659,223.89	7,815,198.99	9,512,961.08
Total expense(Baht/yr)	1,115.44	38,400.36	1,659,223.89	27,006,927.56	28,705,667.25
Net profit(Baht/yr)	86,934.56	20,140,896.21	6,047,724,758.61	64,899,046,944.07	70,966,999,533.45
Total expense/ Revenue	1.27%	0.19%	0.03%	0.04%	0.04%

From the table above in Sub-basin RL shown that after applying uniform tax for each activities. Thus, the emission reduce to meet the standard limits and abatement cost is lower than the profit in every activities.

Table 5-63: Comparable between Non-uniform tax and Uniform tax in sub-basin RL

Sub basin RL		**Non-uniform(X)**	**Uniform(X-alpha)**	**Different(alpha)**
Tax rate	(Baht/KgBOD)		0.29	
Influent	(Kg-BOD/yr)	44,257,404.72	44,257,404.72	
Effluent	(Kg-BOD/yr)	32,737,500.14	32,803,314.06	65,813.92
Effluent Std.	(Kg-BOD/yr)	33,193,053.54	33,193,053.54	
%Reduction	(Government)	25.00%	25.00%	
%Reduction	(Active)	26.03%	25.88%	0.00
Revenue	(Baht/yr)	70,995,705,200.70	70,995,705,200.70	
Cost of abatement	(Baht/yr)	1,480,023,690.04	19,192,706.17	-1,460,830,983.86
Tax expense	(Baht/yr)	24,595,978.84	9,512,961.08	-15,083,017.76
Total expense	(Baht/yr)	1,504,619,668.88	28,705,667.25	-1,475,914,001.63
Net profit	(Baht/yr)	69,491,085,531.82	70,966,999,533.45	1,475,914,001.63
Totalexpense/Revenue		2.12%	0.04%	-2.08%

The result of comparing Non-uniform tax and Uniform tax in sub-basin RL. Uniform tax has less cost of abatement about 1,460,830,983.86 Baht, less tax expense about 15,083,017.76 Baht, less total expense about 1,475,914,001.63 Baht, and gain more net profit about 1,475,914,001.63 Baht.

The effect of the effluent charge

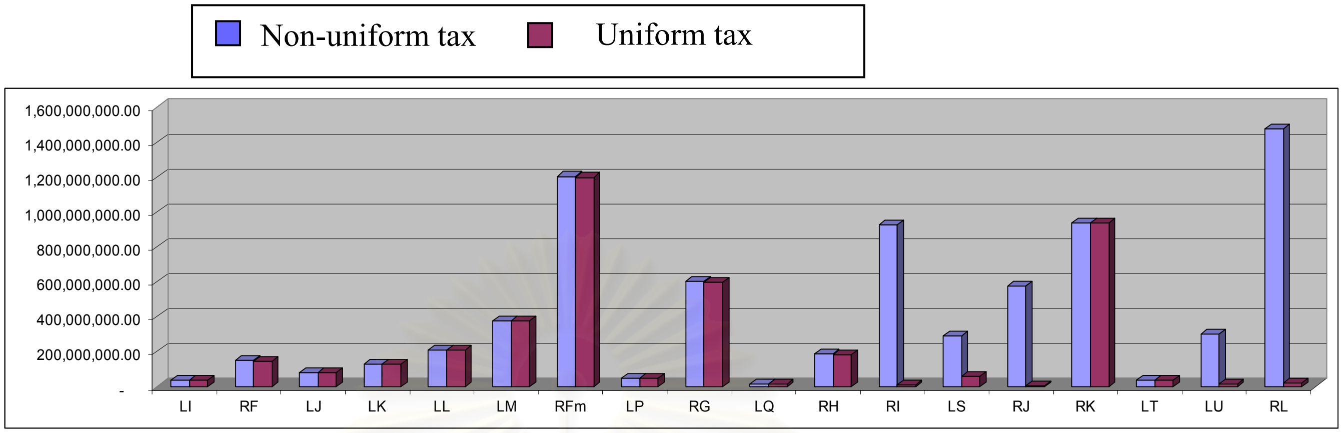

Figure 5-5: Comparable of cost of abatement between Non-uniform and Uniform tax in each sub-basin

Form the figure above show that in sub-basin RI, LS, RJ, LU and RL the abatement cost of Non-uniform tax is vastly different from uniform tax. Because the marginal abatement cost curve of some activities has steep slope until first abatement unit is higher than the last abatement unit of others. Thus, these main point sources has fully spend tax expenses.

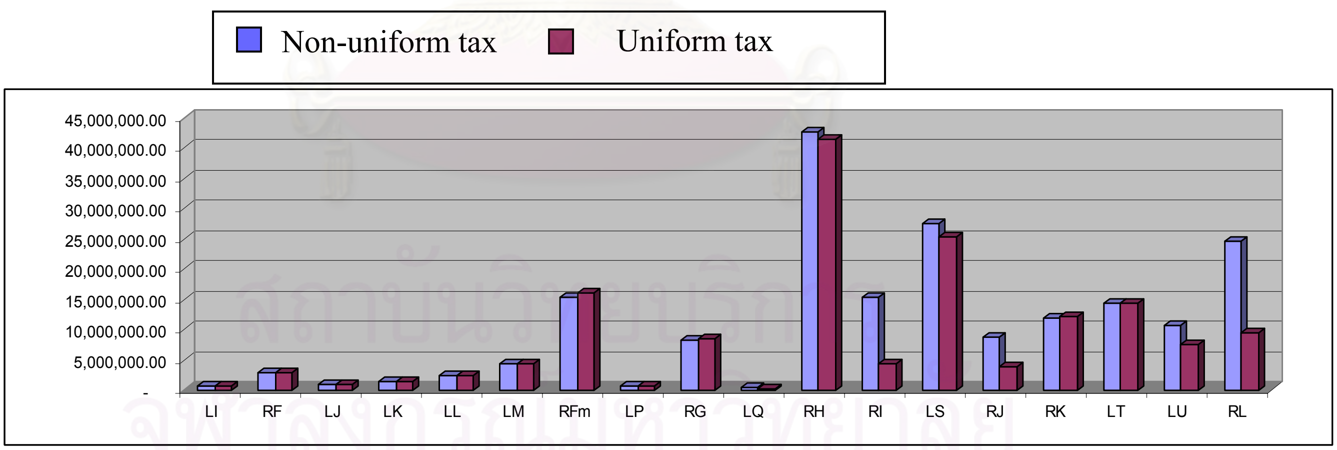

Figure 5-6: Comparable of Tax expense between Non-uniform and Uniform tax in each sub-basin

From the Figure above, although sub-basin RI, LS, RJ, LU and RL have fully spend tax expense, the tax expense of Uniform tax in sub-basin RI and RJ which have tax expense great lower than Non-Uniform tax. Because the marginal abatement cost curve in that sub-basin has a great different. Due to the activity has lower marginal abatement cost and has reduced the marginal abatement cost until the ambient water quality passed the standard.

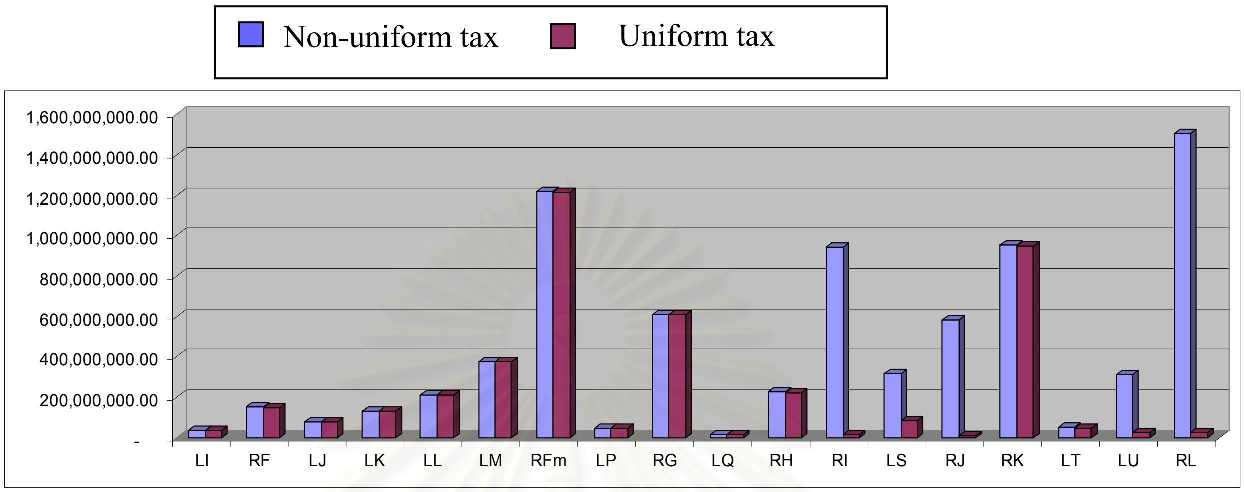

Figure 5-7: Comparable of Total expense between Non-uniform and Uniform tax in each sub-basin

From the Figure above, The total expense of Uniform tax in every sub-basins are lower than Non-Uniform tax. Vastly different in Sub-basin RI, LS, RJ, LU and RL due to the efficiency of uniform tax theory which has been explained previously.

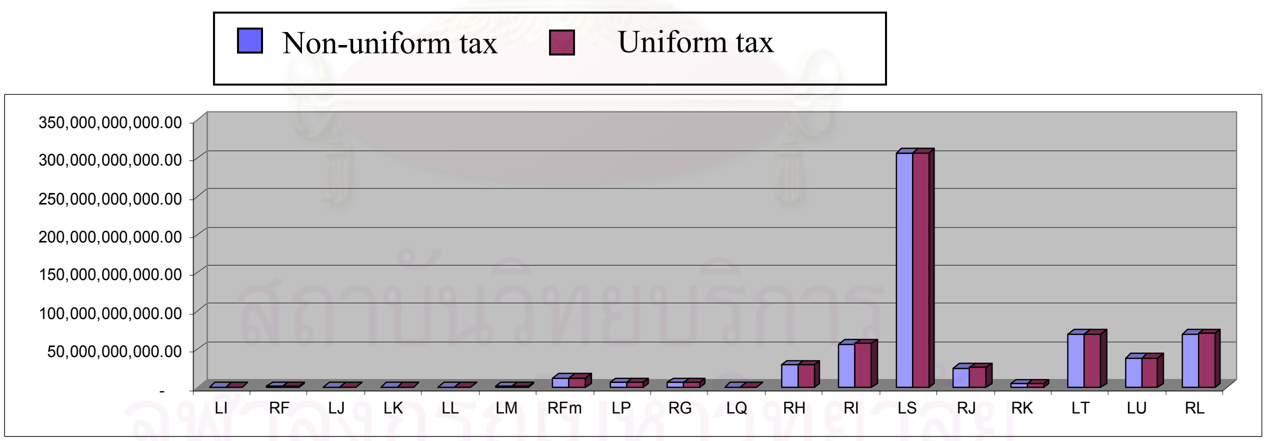

Figure 5-8: Comparable of Net profit between Non-uniform and Uniform tax in each sub-basin

Form the tax expense and cost of abatement figure above show that some sub-basins are vastly different., when compare with net profit. Thus, Non-uniform and Uniform tax has slightly different for the net profit. Due to the total expense or total pollution control cost is very cheap when comparing to the revenue. This mean that if Non-uniform or Uniform tax has been applied, the activities will not face any trouble.

There is an abundance of literature on the effect of effluent charge which has been widely introduced in many countries. One study which has looked at the issue by Indab et al. (2003) who studied effluent charge for Sarangani Bay in Philippines. However, the existing effluent charge scheme is under CAC scheme does not help to reduce the water pollution, they recommended newly effluent charge scheme to increase the pollution reduction which generated a 92% increase in pollution reduction. However, 23% increase in total abatement cost. Our study uses the uniform tax scheme as a management for protecting and maintaining good water quality. Moreover uniform tax cause total abatement cost decreased comparing to Non-uniform tax.

Another study in China by Dasgupta (1996) which of water pollution abatement by Chinese industry determined that the current regulatory system provides an economic incentive to abate by charging a levy on pollution in excess of the standard. However, the study results suggest that changing to a full emissions charge system would greatly reduce overall abatement costs. Uniform pollution charges could produce much higher environmental quality. If China emissions charge system is adopted, it would seem appropriate to give local regulators the authority to adapt charges to local circumstances. Our study compares Non-uniform tax and Uniform tax is suitable to adapt charges system. However, the conclusion of this study is similarity to our research which say that the uniform tax is the suitable effluent charge scheme to apply.

Nevertheless, there is some article point the disadvantage of applied effluent charge scheme cause. The study Peretto (2007) in the effects of effluent taxes on firms' allocation of resources to cost-reducing and emission-reducing. In terms of environmental benefits, the tax induces a positive rate of pollution abatement that offsets the "dirty" side of economic growth. A tax set at an endogenous rate that holds constant the tax burden per unit of output, consequently, an impact of increased cost unit of output bring down the marginal revenue of factory or an increased price of products.

CHAPTER VI

CONCLUSION & RECOMMENDATION

6.1 Comparison of Non-Uniform tax and Uniform tax

Table 6-1: Comparison effect of Non-Uniform tax and Uniform tax to Thachin river

	Command&Control **Non-Uniform Tax** (X)	**Market Based Incentive** **Uniform Tax** (X-alpha)	**Different** (alpha)
Effluent (Kg-Bod/yr)	171,933,645.26	173,274,193.21	1,340,547.95
%Reduction (Active)	38.100%	37.617%	-0.483%
Cost of abatement (Baht/yr)	7,579,208,523.25	4,098,278,631.53	-3,480,929,891.71
Tax expense (Baht/yr)	192,982,306.15	156,413,160.39	-36,569,145.76
Total expense (Baht/yr)	7,772,190,829.39	4,254,691,791.92	-3,517,499,037.47
Net profit (Baht/yr)	629,922,275,884.23	633,440,317,645.51	3,518,041,761.28
Total expense / Revenue	1.219%	0.667%	-0.552%

In this model, E is consisting in 2 parts which are Tax and Cost of abatement. When the effluents (E) decrease 1 unit, it generates the tax expense t Baht and the cost abatement increase MAC Baht. Thus, reduction of t Baht which greater than MAC Baht. Polluter continuous reduce effluent (E) unit MAC greater than t Baht. The firm polluter will stop emission. In contrast, Non-uniform tax use price as a tool to reduce the emissions. Thus, there is no competition in sub-basin.

For instance, Tax 1 = MC 1, Tax 2 = MC2 etc, however uniform tax perform as t = MC1, MC2, MC3m MC4 hence the result of this tax is the optimal. The principle of Uniform tax is reducing the first effluent (E) unit, the model will fine to whom has the minimum of MAC , who has the minimum of MAC will the first to reduce effluent (E) and continue reducing until MAC of that polluter higher than other. The model will find the next polluter and repeat the process again however this will be under the standard tax rate which called "Uniform Tax" for any sub-basin.

From the table above, using the uniform tax can effluent more than using Non-uniform, which meet the effluent standard, approximately of 1,344,399.32 Kg-BOD/yr. The cost of abatement of uniform tax is lower than non-uniform tax approximately of 3,480,944,681.53 Baht/year. Moreover the total expenses of uniform tax is lower than non-uniform tax approximately of 3,517,515,764.60 Baht/year which lead to the net profit of Uniform tax is higher than Non-uniform tax approximately of 3,518,058,488.41 Baht.

In conclusion, both of Non-uniform and Uniform tax are reducing efficiently the wastewater emission in Thachin River to meet the standard requirement however, in term of economic, the uniform tax is more efficient than Non-uniform tax as the total expense per revenue of entire river is higher than using Non-uniform tax approximately of 0.552 %.

6.2 Applied the Mathematical decision-making model with other rivers.

In case of using this model apply for other rivers. The procedures are as follows

a) Collected an information is shown in table 3-19

- Finding current situation of BOD loading
- Finding Total Maximum Daily Loading and target of emission reduction
- Specific characteristic of main point sources in the river
- Economic composite of main point sources in the river

b) Followed the procedure from conceptual framework is shown in the figure 3-1

- Developed MAC of each main point sources
- Calculated Tax rate equivalent to CAC
- Simulation by optimization model

Advantage and Disadvantage of Mathematical decision-making model.

The advantages of this model are

- Flexible, this model can be applied with other river by collecting new set of data.
- This model is friendly used with non-technical economist because the mathematical model has already been transformed into excel solver.

The disadvantages of this model are

- Data collection is complicated and time consuming.
- This model can be used with only point sources
- Excel solver use significant parameters which are co-efficient set of each main point source. Arrived of MAC by running the statistical program is complicated for non technical economist.

Remark

- In case of central treatment plant has been established, this model can be used. It can be used however, the first step is finding the following:-
  - Distinguishable types of main point source are covered by Central treatment plant.
  - Identified the number of main point sources is using the central treatment plant.
  - Identified the location of main point sources and located in which sub-basin.
  - Considered the wastewater treatment technology is using the same technology.
  - If main point source uses the same technology as the model, identified sub-basin that central treatment plant is located.
  - If the treatment technology changed, MAC would re-run the program which assumed that central treatment plant is other point sources.

- Distance of point source is effected to emission tax charge
    - Emission tax charge is collected as the same rate as shown in the report. Due to the data collection from PCD were considered the self purification rate, in form of distance of the river, distance of river network e.g. the polluter is located 1 km. away from the river. 1 km. distance of self purification is equal to 20%. If this polluter is located in sub-basin LI, emission tax rate is the same rate as in the report. Because emission tax rate has been set as same as target of mission reduction 50%. Thus, when upstream is reduced pollution loading at 50%, downstream is also reduced at same rate.
- If the concentration based effluent is concentrated, is this model working?
    - Yes, it is, however, the polluter has to pay more tax expense.
      Due to the polluter release more amount of pollution loading which show that the polluter is interested to pay less abatement cost. Therefore tax expense is increased by the volume of pollutant loading multiply by tax rate.

6.3 Emission tax charge apply for main point sources

a) First, is measuring BOD at end-of-pipe, where C is the average wastewater BOD or effluent BOD from generating-source of interest (g-BOD /cu.m.)

b) Second, BOD is brought to calculate by using the equation in the table below. By Q is equal to P where P is numbers of wastewater generating unit for source of interest (unit/day). And V is quantity of wastewater or effluent per wastewater generating unit of the source of interest (cu.m./unit).

c) Third, finding L by using the equation below. Then multiply L by emission tax charge which is shown in the table.

In production line, that will be released discharges into a river, this discharge may direct from production line or come from treatment plant, which discharges level will be related with

$$L = \overline{C}VP \qquad (1)$$

When L = wastewater BOD load or effluent BOD load from generating-source of interest (g BOD/day)

C = average wastewater BOD or effluent BOD from generating-source of interest (g /m^3)

V = quantity of wastewater or effluent per wastewater generating unit of the source of interest (m^3/unit)

P = numbers of wastewater generating unit for the source of interest (unit/day)

The selected values for three variables in the above equation for each type of generating source are as follows.

1) Pig farms

P = Using numbers of pigs in the farm

V and C depends on the size of pig farms, as follows

Farm size	V (L/pig-day)	C (mg/l)
<500 pigs	20	1,500
500-5,000 pigs	15	2,500
>5,000 pigs	10	3,000

Source: PCD, (2005a)

2) Aquatic animal farms

P = Use the area of cultivating pond (rai)

2.1) Use V and C from 2 types of aquatic animal farm: prawn farming and fish farming. According to the registration data, there is only 1.5 % of total aquatic animal framing area in Thachin River Basin that is used for cultivation of other aquatic animals (Fishery Department, B.E. 2548). Since effluent from meat-eating fish pond will go to plant-eating fish farm before being discharged. Therefore, the selected values of V and c used as representative of effluent form fish farm are the value from effluent of the plant-eating fish pond only PCD.

2.2) The values of V for effluent from two types of aquatic animal farms are the yearly average values. The C values are the average values of effluent being discharged for each cultivating period as follows

Type of aquatic animal	V (m^3/rai-day)	C (mg/l)
Plant-eating fish	11.4	20.0
prawn	25.6	10.25

Source: PCD, (2005a)

2.3) Effluent BOD load from aquatic animal farm in each province is area-weighted average, according to the ratio of area used for farming of these 2 types of aquatic animal in each province. (The type of aquatic animal can not be differentiating based on the satellite photo).

V			C
Province	Ratio of area as aquatic animal farming[1] prawn	fish	Effluent BOD load from aquatic animal farm (kg/rai-day)
Samutsakorn	0.84:	0.16	0.26
Nakornpathom	0.64:	0.36	0.25
Supanburi	0.44:	0.56	0.24
Kanjanaburi	0.06:	0.94	0.23
Chainatr	0.04:	0.96	0.23
Utaitani	0.02:	0.98	0.23

Source: PCD, (2005a)

3) Community

P = Use number of people in the community

V and C = Use the average values from the survey for flow and characteristics of wastewater of sub-district municipality and municipality in Thachin River Basin under this project as follows

Community size	V (L/person-day)	C (mg/l)
Sub-district municipality	120	105
Municipality, metropolitan	300	120

Source: PCD, (2005a)

4) Factory generating wastewater from production process

P = Use daily quantity of raw material used or products produced

V and C = Use the average volume of wastewater from the factory (PCD, 2005a).

6.4 Wastewater from Non-point sources

In generally, any types of polluter such as point sources and non-point sources, which discharge wastewater into the river, are followed the same regulation, however, non-point sources have an uncertain form of emission. Therefore, monitoring and reducing the volume of wastewater is complicated for an implementation. Hence, the permit system of non-point sources, which has the volume of BOD higher than TMDL in Thachin River, is an improper system (PCD, 2005a)

The suitable procedure for reducing the emission discharge of Non-point sources are as follows:

6.4.1 Developed good agriculture practice in order to improve the production efficient. The procedures are as follows,

1) Given environmental agriculture handbook to the farmers
2) Farmers have a financial privilege supported by government financial institute.
3) Created market based instrument such as certify product or certify farm

6.4.2 Created management scheme reduce water pollution from Non-point sources. The procedures are as follows,

1) Encouraged the local government by providing an information of pollution generator.
2) Given a financial support to the farmers.
3) Given directly extra financial supports to any projects are concerned to pollution system.
4) Publish announcement or given information of agriculture water pollution.
5) Encouraged communities participate in monitoring the quality of water sources.

Nevertheless, from the polluter-pay –principle said that all pollution sources are responsible for preserving the water quality. Thus, for long term periods the government has to develop system which can control the pollution from Non-point sources. However, at present, there is non mechanism for controlling the wastewater from Non-point sources.

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APPENDIX

APPENDIX A

Table A-1: Industrial Effluent Standards

Parameters	Standard Values	Method for Examination
1. pH value	5.5-9.0	pH Meter
2. Total Dissolved Solids (TDS)	Not more than 3,000 mg/l depending on receiving water or type of industry under consideration of PCC but not exceed 5,000 mg/l Not more than 5,000 mg/l exceed TDS of receiving water having salinity of more than 2,000 mg/l or TDS of sea if discharge to sea	Dry Evaporation 103-105 °C, 1 hour
3. Suspended solids (SS)	not more than 50 mg/l depending on receiving water or type of industry or wastewater treatment system under consideration of PCC but not exceed 150 mg/l	Glass Fiber Filter Disc
4. Temperature	not more than 40°C	Termometer during the sampling
5. Color and Odor	not objectionable	Not specified
6. Sulphide as H_2S	not more than 1.0 mg/l	Titrate
7. Cyanide as HCN	not more than 0.2 mg/l	Distillation and Pyridine Barbituric Acid Method
8. Fat, Oil & Grease (FOG)	not more than 5.0 mg/l depending of receiving water or type of industry under consideration of PCC but not exceed 15.0 mg/l	Sovent Extraction by Weight
9. Formaldehyde	not more than 1.0 mg/l	Spectrophotometry
10.Phenols	not more than 1.0 mg/l	Distillation and 4-Aminoantipyrine Method
11.Free Chlorine	not more than 1.0 mg/l	lodometric Method
12.Pesticides	not detectable	Gas-Chromatography

Table A-1: (continued)

Parameters	Standard Values	Method for Examination
13.Biochemical Oxygen Demand (BOD)	not more than 20 mg/l depending on receiving water or type of industry under consideration of PCC but not exceed 60 mg/l	-Azide Modification at 20 °C , 5 days
14.Total Kjedahl Nitrogen (TKN)	not more than 100 mg/l depending on receiving water or type of industry under consideration of PCC but not exceed 200 mg/l	Kjeldahl
15.Chemical Oxygen Demand (COD)	not more than 120 mg/l depending on receiving water of type of industry under consideration of PCC but not exceed 400 mg/l	Potassium Dichromate Digestion
16.Heavy metals		
1. Zinc (Zn)	not more than 5.0 mg/l	Atomic Absorption Spectro Photometry; Direct Aspiration or Plasma Emission Spectroscopy ; Inductively Coupled Plama : ICP
2. Chromium (Hexavalent)	not more than 0.25 mg/l	
3. Chromium (Trivalent)	not more than 0.75 mg/l	
4. Copper (Cu)	not more than 2.0 mg/l	
5. Cadmium (Cd)	not more than 0.03 mg/l	
6. Barium (Ba)	not more than 1.0 mg/l	
7. Lead (Pb)	not more than 0.2 mg/l	
8. Nickel (Ni)	not more than 1.0 mg/l	
9. Manganese (Mn)	not more than 5.0 mg/l	
10. Arsenic (As)	not more than 0.25 mg/l	Atomic Absorption Spectrophotometry; Hydride Generation, or Plasma Emission Spectroscopy; Inductively Coupled Plasma : ICP
11. Selenium (Se)	not more than 0.02 mg/l	
12. Mercury (Hg)	not more than 0.005 mg/l	Atomic Absorption Cold Vapour Techique

Remarks : 1) PCC Pollution Control Committee

2) The standards were summerized from the Notification of the Ministry of Science, Technology and Environment, No. 3, B.E. 2539 (1996) and it specifies that pollution sources that the above standards are to be applied are factories group II and III issues under the Factory Act B.E.2535 (1992) and every kind of industrial estates.

3) Notification of the Pollution Control Committee, No. 3, B.E. 2539 (1996) dated August 20, B.E. 2539 (1996) has issued types of factories (category of factories issued under the Factory Act B.E.2535 (1992) that are allowed to discharge effluent having different standards from the Ministerial Notification No. 3 above as follows :

1. BOD up to 60 mg/l
   - animal furnishing factories (category 4 (1))
   - starch factories (category 9 (2))
   - food from starch factories (category 10)
   - textile factories (category 15)
   - tanning factories (category 22)
   - pulp and paper factories (category 29)
   - chemical factories (category 42)
   - pharmaceutical factories(category 46)
   - frozen food factories (category 92)
2. COD up to 400 mg/l
   - food furnishing factories (category 13 (2))
   - animal food factories (category 15 (1))
   - textile factories (category 22)
   - pulp and paper factories (category 38)
3. TKN
   - 100 mg/l - effective after 1 year from the date published in the Royal Government Gazette of the Ministerial Notification No. 4
   - 200 mg/l - effective after 2 year from the date published in the Royal Government Gazette of the Ministerial Notification No. 4 for the following factories:
     1. food furnishing factories (category 13 (2))
     2. animal food factories (category 15 (1))

Sources : 1. Notification the Ministry of Science, Technology and Environment, No. 3, B.E.2539 (1996) issued under the Enhancement and Conservation of the National Environmental Quality Act B.E.2535 (1992), published in the Royal Government Gazette, Vol. 113 Part 13 D, dated February 13, B.E.2539 (1996)

Table A-2: Classification and Objectives

Classification	Objectives/Condition and Beneficial Usage
Class 1	Extra clean fresh surface water resources used for : (1) conservation not necessary pass through water treatment process require only ordinary process for pathogenic destruction (2) ecosystem conservation where basic organisms can breed naturally
Class 2	Very clean fresh surface water resources used for : (1) consumption which requires ordinary water treatment process before use (2) aquatic organism of conservation (3) fisheries (4) recreation
Class 3	Medium clean fresh surface water resources used for : (1) consumption, but passing through an ordinary treatment process before using (2) agriculture
Class 4	Fairly clean fresh surface water resources used for : (1) consumption, but requires special water treatment process before using (2) industry
Class 5	The sources which are not classification in class 1-4 and used for navigation.

Source : Notification of the National Environmental Board, No. 8, B.E. 2537 (1994), issued under the Enhancement and Conservation of National Environmental Quality Act B.E.2535 (1992) , published in the Royal Government Gazette, Vol. 111, Part 16, dated February 24, B.E.2537 (1994).

Table A-3: Surface Water Quality Standard

Parameter[1/]	Units	Statistics	Standard Value for Class[2/]					Methods for Examination
			Class1	Class2	Class3	Class4	Class5	
1. Colour,Odour and Taste	-	-	n	n'	n'	n'	-	-
2. Temperature	C°	-	n	n'	n'	n'	-	Thermometer
3. pH	-	-	n	5-9	5-9	5-9	-	Electrometric pH Meter
4. Dissolved Oxygen (DO)[2/]	mg/l	P20	n	6.0	4.0	2.0	-	Azide Modification
5. BOD (5 days, 20°C)	mg/l	P80	n	1.5	2.0	4.0	-	Azide Modification at 20°C , 5 days
6. Total Coliform Bacteria	MPN/100 ml	P80	n	5,000	20,000	-	-	Multiple Tube Fermentation Technique
7. Fecal Coliform Bateria	MPN/100 ml	P80	n	1,000	4,000	-	-	Multiple Tube Fermentation Technique
8. NO_3 -N	mg/l	-	n	5.0			-	Cadmium Reduction
9. NH_3 -N	mg/l	-	n	0.5			-	Distillation Nesslerization
10.Phenols	mg/l	-	n	0.005			-	Distillation,4-Amino antipyrene
11.Copper (Cu)	mg/l	-	n	0.1			-	Atomic Absorption -Direct Aspiration
12.Nickle (Ni)	mg/l	-	n	0.1			-	Atomic Absorption -Direct Aspiration
13.Manganese (Mn)	mg/l	-	n	1.0			-	Atomic Absorption -Direct Aspiration
14.Zinc (Zn)	mg/l	-	n	1.0			-	Atomic Absorption -Direct Aspiration
15.Cadmium (Cd)	mg/l	-	n	0.005* 0.05**			-	Atomic Absorption -Direct Aspiration
16.Chromium Hexavalent	mg/l	-	n	0.05			-	Atomic Absorption -Direct Aspiration

Table A-3: (continued)

Parameter[1/]	Units	Statistics	Standard Value for Class[2/]					Methods for Examination
			Class1	Class2	Class3	Class4	Class5	
17.Lead (Pb)	mg/l	-	n	0.05	-			Atomic Absorption - Direct Aspiration
18.Total Mercury (Total Hg)	mg/l	-	n	0.002	-			Atomic Absorption-Cold Vapour Technique
19.Arsenic (As)	mg/l	-	n	0.01	-			Atomic Absorption - Direct Aspiration
20.Cyanide (Cyanide)	mg/l	-	n	0.005	-			Pyridine-Barbituric Acid
21.Radioactivity - Alpha - Beta	Becqurel /l	-	n	0.1 1.0	-			Gas-Chromatography
22.Total Organochlorine Pesticides	mg/l	-	n	0.05	-			Gas-Chromatography
23.DDT	µg/l	-	n	1.0	-			Gas-Chromatography
24.Alpha-BHC	µg/l	-	n	0.02	-			Gas-Chromatography
25.Dieldrin	µg/l	-	n	0.1	-			Gas-Chromatography
26.Aldrin	µg/l	-	n	0.1	-			Gas-Chromatography
27.Heptachlor & Heptachlorepoxide	µg/l	-	n	0.2	-			Gas-Chromatography
28.Endrin	µg/l	-	n	None	-			

Remark :

P Percentile value

n naturally

n' naturally but changing not more than 3°C

* when water hardness not more than 100 mg/l as $CaCO_3$

** when water hardness more than 100 mg/l as $CaCO_3$

Based on Standard Methods for the Examination of Water and Wastewater recommended by APHA : American Public Health Association, AWWA : American Water Works Association and WPCF : Water Pollution Control Federation

Source : Notification of the National Environmental Board, No. 8, B.E. 2537 (1994), issued under the Enhancement and Conservation of National Environmental Quality Act B.E.2535 (1992) , published in the Royal Government Gazette, Vol. 111, Part 16, dated February 24, B.E.2537 (1994).

Table A-4: Classification of Water Resources for each Region

River	Control Areas (km. from River Mouth)	Water Quality Standards (Same as Standards of Water Classification)	Source
Central Region			
1. Chao Phraya River	Part 1 From Pra Samutchedi Samutprakarn Province To the Old Nontaburi City Hall (Km. 7 to 62) Part 2 From the Old Nontaburi City Hall to Pompetch in Ayutthaya (Km. 62 to 142) Part 3 Frorm Pompetch in Ayutthaya to the begining of Chaopraya River in Nakhornsawan Province (Km.142 to 379)	4 3 2	Notification of Pollution Control Department, published in the Royal Government Gazette, Vol. 111, Part 62, dated August 4, B.E.2537 (1994).
2. Thachin River	Part 1 From River Mouth Muang ,Samutrprakarn to Nakhornchaisri, Nakhornpathom (Km. 0 to 82) Part 2 From Nakhornchaisri, Nakhornpathom to Pho pra ya Watergate, Muang Suphanburi (Km.82 to 202) Part 3 From Pho pra ya Watergate, Muang Suphanburi to Mouth of Makhamtao Chanel, Watsing Chainat (Km. 202 To 325)	4 3 2	
3. Bang Pakong, Nakorn Nayok, and Prachinburi River	1. Bang Pakong River from river mouth to Bansang, Prachinburi Province (122 KM. Distance) 2. Nakorn Nayok River from Bansang, Prachinburi Province to Amphur Muang, Nakorn Nayok Province (84 Km. Distance) 3. Prachinburi River from Bansang, Prachinburi Province to Amphur Muang, Prachinburi Province (63 Km. Distance)	3 3 2	
4. Maeklong River	From River Mouth (Shell Oil Terminal) Samutrsongkram to Pak preak ,Muang Kanchanaburi (Km 0 to 140)	3	

Table A-4: (continued)

River	Control Areas (km. from River Mouth)	Water Quality Standards (Same as Standards of Water Classification)	Source
Northeastern Region			
1. Songkram River	from Ta-uten, Nakhonpanom Province(km.0) to Sohpisai , Nongkai Province(km.189)	3	Notification of Pollution Control Department, published in the Royal Government Gazette, Vol. 116, Part 53, dated July 6, B.E.2542 (1999).
2. Phong River	from Kosoompisai, Mahasarakarm Province(km.0) to Ubonrat Dam, Khonkhean Province(km.140)	3	
3. Chi River	from Warinchamrab, Ubonratchatani Province(km.0) to Bankwao, Chaiyaphum Province(km.429)	3	
4. Moon River	from Kongjuim, Ubonratchatani Province(km.0) to Chokchai, Nakhonratchasima Province(km.787)	3	
5. Lamtakong Water	Part 1 from the conjunction with Moon River in Amphur Muang, Nakhonratcharatsima Province (km. 0) to Khonchum Dike in Amphur Muang , Nakhonratchasima Province (km. 24) Part 2 from Khonchum Dike in Amphur Muang , Nakhonratchasima Province (km. 24) to Pakchong,Nakhonratchasima Province (km. 180)	4 3	

Table A-4: (continued)

River	Control Areas (km. from River Mouth)	Water Quality Standards (Same as Standards of Water Classification)	Source
Southern Region			
1. Phetchaburi River	<u>Part 1</u> From River Mouth Banleam ,Petchburi) to Petchaburi Dam, Bahn Kohla-om, Tayang Pecthcburi (Km.0 to 61) <u>Part 2</u> Petchaburi Dam, Bahn Kohla-om, Tayang Pecthcburi to Keangkrajarn Dam, Keangkrajarn Petchaburi Province (Km. 61 to 118)	3 2	Notification of Pollution Control Department, published in the Royal Government Gazette, Vol. 116, Part 72, dated September 9, B.E.2542 (1999).
2. Tapi River-Phum Duang River	**1. Tapi River** <u>Part 1</u> from River mouth in Amphur Muang,Surattani Province (km.0) to Amphur Chawang, Surattani Province (km.184) <u>Part 2</u> from Banwungmaung in Amphur Chawang,Surattani Province (km.184) to Amphur Phipoon, Surattani Province (km.221) **2. Klong Phumduang** from the conjunction with Tapi River and Phumduang River in Amphur Punpin, Surattani Province (km.0) to Ratchaprapa Dam, in Bantakhun, Surattani Province (km.121)	3 2 3	Notification of Pollution Control Department, published in the Royal Government Gazette, Vol. 117, Special Part 10, dated February 2, B.E.2543 (2000).
3. Pattani River	<u>Part 1</u> from river mouth (km.0) to Yarang, Pattani Province (km.19) <u>Part 2</u> from Yarang, Pattani Province (km.19) to Banglang Dam in Bannang, Yala Province (km.128)	3 2	Notification of Pollution Control Department, published in the Royal Government Gazette, Vol. 116, Part 72, dated September 9, B.E.2542 (1999).
4. Pak Phanang River	from river mouth(km.0) to Maisieb Dam in Cha-ued,Nakhonsrithammarat Province(km.109)	3	

APPENDIX B

Table B-1: Properties of Marginal Abatement Cost function (Pig farm)

Dependent Variable: LOG(COST)
Method: Least Squares
Date: 08/17/06 Time: 04:44
Sample(adjusted): 2 1065
Included observations: 1032
Excluded observations: 32 after adjusting endpoints
Convergence achieved after 5 iterations
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.184940	0.073908	-16.03272	0.0000
LOG(F)	0.719655	0.172151	4.180373	0.0000
LOG(I)	0.523361	0.139375	3.755045	0.0002
LOG(E)	-0.136506	0.021854	-6.246217	0.0000
AR(1)	0.201259	0.033135	6.073994	0.0000

R-squared	0.994420	Mean dependent var	8.207981
Adjusted R-squared	0.994398	S.D. dependent var	1.671726
S.E. of regression	0.125122	Akaike info criterion	-1.314229
Sum squared resid	16.07810	Schwarz criterion	-1.290298
Log likelihood	683.1420	F-statistic	45754.54
Durbin-Watson stat	1.830169	Prob(F-statistic)	0.000000
Inverted AR Roots	.20		

Table B-2: Properties of Marginal Abatement Cost function (Urban Community)

Dependent Variable: LOG(COST)
Method: Least Squares
Date: 08/16/06 Time: 23:47
Sample(adjusted): 2 525
Included observations: 488
Excluded observations: 36 after adjusting endpoints
Convergence achieved after 5 iterations
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.221105	0.359317	-0.615349	0.5386
LOG(F)	0.808064	0.166288	4.859434	0.0000
LOG(I)	0.472857	0.166421	2.841336	0.0047
LOG(E)	-0.279287	0.013594	-20.54528	0.0000
AR(1)	0.957445	0.013936	68.70269	0.0000

R-squared	0.997401	Mean dependent var	9.907555
Adjusted R-squared	0.997379	S.D. dependent var	1.822383
S.E. of regression	0.093296	Akaike info criterion	-1.895896
Sum squared resid	4.204060	Schwarz criterion	-1.852962
Log likelihood	467.5986	F-statistic	46333.64
Durbin-Watson stat	1.990792	Prob(F-statistic)	0.000000
Inverted AR Roots	.96		

Table B-3: Properties of Marginal Abatement Cost function (Aqua Culture)

Dependent Variable: LOG(COST)
Method: Least Squares
Date: 03/28/07 Time: 06:24
Sample(adjusted): 60 3075
Included observations: 683
Excluded observations: 2333 after adjusting endpoints
Convergence achieved after 8 iterations
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.679473	0.003994	921.2608	0.0000
LOG(F)	0.466506	1.24E-08	37686663	0.0000
LOG(I)	0.544964	1.47E-08	37126864	0.0000
LOG(E)	-0.011470	2.31E-09	-4975406.	0.0000
AR(1)	1.000000	1.04E-07	9630947.	0.0000

R-squared	1.000000	Mean dependent var	15.55306
Adjusted R-squared	1.000000	S.D. dependent var	1.403957
S.E. of regression	2.10E-10	Akaike info criterion	-41.71836
Sum squared resid	3.00E-17	Schwarz criterion	-41.68523
Log likelihood	14251.82	F-statistic	7.59E+21
Durbin-Watson stat	3.004338	Prob(F-statistic)	0.000000

Inverted AR Roots 1.00
Estimated AR process is nonstationary

Table B-4: Properties of Marginal Abatement Cost function (Industry)

Dependent Variable: LOG(COST)
Method: Least Squares
Date: 03/27/07 Time: 07:04
Sample(adjusted): 1 8100
Included observations: 1393
Excluded observations: 6707 after adjusting endpoints
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.706499	0.120808	-22.40325	0.0000
LOG(F)	1.381092	0.035132	39.31115	0.0000
LOG(I)	0.169197	0.026774	6.319535	0.0000
LOG(E)	-0.407217	0.022104	-18.42250	0.0000

R-squared	0.913056	Mean dependent var	9.553845
Adjusted R-squared	0.912868	S.D. dependent var	3.371413
S.E. of regression	0.995177	Akaike info criterion	2.831075
Sum squared resid	1375.634	Schwarz criterion	2.846119
Log likelihood	-1967.844	F-statistic	4862.265
Durbin-Watson stat	1.058904	Prob(F-statistic)	0.000000

APPENDIX C

Table C-1: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin LI

Subbasin Profit	388177072.4
Transfer coefficient	0
Subbasin Emission	169749.6728
At-1	475393.6692
A	169749.6728
A'	170,033.80
Emission Pass	Approve

Pig Farm Sector			
Constant		Revenue	1758652
P	587	Abatement Cost	22144.85
Q	2996	T	0.15
alpha	5.5	Emission	20152.663
beta	13.6		
F	16478	Pig Farm Profit	1733484.3
I	40745.6		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector			
Constant		Revenue	7147097.7
P	0	Abatement Cost	766520.77
Q	31139	T	3.09
alpha	37.31962	Emission	69281.292
beta	4.452037		
F	1162096	Urban Profit	6166497.7
I	138632		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector			
Constant		Revenue	136036628
P	55502500	Abatement Cost	35726101
Q	2.451	T	6.11
alpha	3194027	Emission	67066.826
beta	54750		
F	7828561	Aquaculture Profit	99900748
I	134192.3		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector			
Constant		Revenue	280395717
P	-	Abatement Cost	13810.31
Q	12055.95	T	0.42
alpha	2.761833	Emission	13248.892
beta	2.197901		
F	33296.52	Factory Profit	280376342
I	26497.78		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	388,279,845.67	Uniform Tax	3.9
Transfer coefficient	-		
Subbasin Emission	166,177.83		
At-1	475,864.86		
A	166,177.83		
A'	170,033.80		
		Emission Pass	Approve

Pig Farm Sector			
Constant		Revenue	1758652
P	587	Abatement Cost	32751.075
Q	2996	T	3.9
alpha	5.5	Emission	1146.3353
beta	13.6		
F	16478	Pig Farm Profit	1721430.2
I	40745.6		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector			
Constant		Revenue	7147097.7
P	0	Abatement Cost	806486.1
Q	31139	T	3.9
alpha	37.31962	Emission	57754.086
beta	4.452037		
F	1162096	Urban Profit	6115370.6
I	138632		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector			
Constant		Revenue	136036628
P	55502500	Abatement Cost	35544679
Q	2.451	T	3.9
alpha	3194027	Emission	104537.75
beta	54750		
F	7828561	Aquaculture Profit	100084251
I	134192.3		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector			
Constant		Revenue	280395717
P	-	Abatement Cost	26238.364
Q	12055.95	T	3.9
alpha	2.761833	Emission	2739.656
beta	2.197901		
F	33296.52	Factory Profit	280358794
I	26497.78		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-2: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin RF

Subbasin Profit	1098741156
Transfer coefficient	0
Subbasin Emission	475393.6692
At-1	0
A	475,393.67
A'	476,298.02
Emission Pass	Approve

Pig Farm Sector

	Constant		
		Revenue	17527820
P	587	Abatement Cost	2078352.19
Q	29860	T	0.91
alpha	29.20984	Emission	311767.19
beta	69.79607		
F	872205.8	Pig Farm Profit	15165759.7
I	2084111		
	Co-effcient		
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

	Constant		
		Revenue	17594498
P	0	Abatement Cost	3490648
Q	76657	T	14.96
alpha	49.65039	Emission	65166.587
beta	5.6686		
F	3806050	Urban Profit	13128958
I	434537.9		
	Co-effcient		
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

	Constant		
		Revenue	1018692885
P	55502500	Abatement Cost	142150208
Q	18.354	T	20.65
alpha	1674357	Emission	78957.0196
beta	28684.54		
F	30731143	Aquaculture Profit	874912215
I	526476		
	Co-effcient		
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

	Constant		
		Revenue	195685865
P	-	Abatement Cost	107759.18
Q	22849	T	2.25
alpha	5.948243	Emission	19502.873
beta	5.698083		
F	135911.4	Factory Profit	195534224
I	130195.5		
	Co-effcient		
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	1,100,937,275.94	Uniform Tax	5.92
Transfer coefficient	-		
Subbasin Emission	475,864.86		
At-1	-		
A	475,864.86		
A'	476,298.02		
		Emission Pass	Approve

Pig Farm Sector

	Constant		
		Revenue	17527820
P	587	Abatement Cost	2602570.85
Q	29860	T	5.92
alpha	29.20984	Emission	60011.2164
beta	69.79607		
F	872205.8	Pig Farm Profit	14569982.7
I	2084111		
	Co-effcient		
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

	Constant		
		Revenue	17594498
P	0	Abatement Cost	2851087
Q	76657	T	5.92
alpha	49.65039	Emission	134505.24
beta	5.6686		
F	3806050	Urban Profit	13947140
I	434537.9		
	Co-effcient		
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

	Constant		
		Revenue	1018692885
P	55502500	Abatement Cost	140150442
Q	18.354	T	5.92
alpha	1674357	Emission	271541.365
beta	28684.54		
F	30731143	Aquaculture Profit	876934918
I	526476		
	Co-effcient		
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

	Constant		
		Revenue	195685865
P	-	Abatement Cost	142571.66
Q	22849	T	5.92
alpha	5.948243	Emission	9807.0415
beta	5.698083		
F	135911.4	Factory Profit	195485236
I	130195.5		
	Co-effcient		
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-3: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin LJ

Subbasin Profit	261682595
Transfer coefficient	0
Subbasin Emission	138337.465
At-1	169749.673
A	138337.465
A'	138,463.74
Emission Pass	Approve

Pig Farm Sector

Constant			
P	0	Revenue	0
Q	0	Abatement Cost	0
alpha	0	T	0
beta	0	Emission	0
F	0		
I	0	Pig Farm Profit	0
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
P	0	Revenue	397532.8
Q	1732	Abatement Cost	50370.59
alpha	43.8	T	3.81
beta	4.745	Emission	3692.354
F	75861.6	Urban Profit	333094.3
I	8218.34		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	3.02E+08
Q	5.437	Abatement Cost	79343470
alpha	3193750	T	6.8
beta	54750	Emission	133833.7
F	17364419	Aquaculture Profit	2.22E+08
I	297675.8		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
P	-	Revenue	39866071
Q	803	Abatement Cost	21409.36
alpha	34.74545	T	10.74
beta	2.245455	Emission	811.395
F	27900.6	Factory Profit	39835947
I	1803.1		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	261,684,530.41
Transfer coefficient	-
Subbasin Emission	138,304.08
At-1	166,177.83
A	138,304.08
A'	138,463.74
Uniform Tax	6.75
Emission Pass	Approve

Pig Farm Sector

Constant			
P	0	Revenue	0
Q	0	Abatement Cost	0
alpha	0	T	0
beta	0	Emission	0
F	0	Pig Farm Profit	0
I	0		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
P	0	Revenue	397532.8
Q	1732	Abatement Cost	57069.2
alpha	43.8	T	6.75
beta	4.745	Emission	2361.288
F	75861.6	Urban Profit	324524.9
I	8218.34		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	301767093
Q	5.437	Abatement Cost	79336830
alpha	3193750	T	6.75
beta	54750	Emission	134813.78
F	17364419	Aquaculture Profit	221520270
I	297675.8		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
P	-	Revenue	39866071
Q	803	Abatement Cost	18714.59
alpha	34.74545	T	6.75
beta	2.245455	Emission	1129.021
F	27900.6	Factory Profit	39839736
I	1803.1		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-4: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin LK

Subbasin Profit	359937611
Transfer coefficient	0
Subbasin Emission	219435.58
At-1	138337.465
A	219435.58
A'	219,631.34
Emission Pass	Approve

Pig Farm Sector

Constant			
P	0	Revenue	0
Q	0	Abatement Cost	0
alpha	0	T	0
beta	0	Emission	0
F	0		
I	0	Pig Farm Profit	0
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
P	0	Revenue	428977.3
Q	1869	Abatement Cost	30000.75
alpha	24.20492	T	3.8
beta	2.622199	Emission	2204.954
F	45238.99		
I	4900.891	Urban Profit	390597.8
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	489809563
Q	8.825	Abatement Cost	128785381
alpha	3193750	T	6.8
beta	54750	Emission	217230.63
F	28184844	Aquaculture Profit	359547013
I	483168.8		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
P	0	Revenue	0
Q	0	Abatement Cost	0
alpha	0	T	0
beta	0	Emission	0
F	0	Factory Profit	0
I	0		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	359,938,985.24	Uniform Tax	6.77
Transfer coefficient	-		
Subbasin Emission	219,586.15		
At-1	138,304.08		
A	219,586.15		
A'	219,631.34	Emission Pass	Approve

Pig Farm Sector

Constant			
P	0	Revenue	0
Q	0	Abatement Cost	0
alpha	0	T	0
beta	0	Emission	0
F	0		
I	0	Pig Farm Profit	0
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
P	0	Revenue	428977.3
Q	1869	Abatement Cost	34031.93
alpha	24.20492	T	6.77
beta	2.622199	Emission	1403.94
F	45238.99		
I	4900.891	Urban Profit	385440.7
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	4.9E+08
Q	8.825	Abatement Cost	1.29E+08
alpha	3193750	T	6.77
beta	54750	Emission	218182.2
F	28184844	Aquaculture Profit	3.6E+08
I	483168.8		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
P	0	Revenue	0
Q	0	Abatement Cost	0
alpha	0	T	0
beta	0	Emission	0
F	0	Factory Profit	0
I	0		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-5: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin LL

Subbasin Profit	581992955
Transfer coefficient	0
Subbasin Emission	353202.434
At-1	219435.58
A	353202.434
A'	353,518.22
Emission Pass	Approve

Pig Farm Sector

Constant			
P	0	Revenue	0
Q	0	Abatement Cost	0
alpha	0	T	0
beta	0	Emission	0
F	0		
I	0	Pig Farm Profit	0
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
P	0	Revenue	1340138
Q	5904	Abatement Cost	32105.65
alpha	8.199336	T	3.8
beta	0.888261	Emission	2359.664
F	48408.88		
I	5244.295	Urban Profit	1299065
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	791077133
Q	14.253	Abatement Cost	207997511
alpha	3193750	T	6.8
beta	54750	Emission	350842.77
F	45520519		
I	780351.8	Aquaculture Profit	580693890
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
P	0	Revenue	0
Q	0	Abatement Cost	0
alpha	0	T	0
beta	0	Emission	0
F	0		
I	0	Factory Profit	0
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	581994449	Uniform Tax	6.78
Transfer coefficient	0		
Subbasin Emission	353366.586		
At-1	219586.15		
A	353,366.59		
A'	353,518.22		
		Emission Pass	Approve

Pig Farm Sector

Constant			
P	0	Revenue	0
Q	0	Abatement Cost	0
alpha	0	T	0
beta	0	Emission	0
F	0		
I	0	Pig Farm Profit	0
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
P	0	Revenue	1340138
Q	5904	Abatement Cost	36431.42
alpha	8.199336	T	6.78
beta	0.888261	Emission	1500.712
F	48408.88		
I	5244.295	Urban Profit	1293531
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	791077133
Q	14.253	Abatement Cost	207990565
alpha	3193750	T	6.78
beta	54750	Emission	351865.87
F	45520519		
I	780351.8	Aquaculture Profit	580700917
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
P	0	Revenue	0
Q	0	Abatement Cost	0
alpha	0	T	0
beta	0	Emission	0
F	0		
I	0	Factory Profit	0
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-6: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin LM

Subbasin Profit	1030805476		
Transfer coefficient	0		
Subbasin Emission	419848.993		
At-1	353202.434		
A	419848.993		
A'	420,241.15	Emission Pass	Approve

Pig Farm Sector

Constant			
		Revenue	0
P	0	Abatement Cost	0
Q	0	T	0
alpha	0	Emission	0
beta	0		
F	0	Pig Farm Profit	0
I	0		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
		Revenue	0
P	0	Abatement Cost	0
Q	0	T	0
alpha	0	Emission	0
beta	0		
F	0	Urban Profit	0
I	0		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
		Revenue	1408819958
P	55502500	Abatement Cost	373727824
Q	25.383	T	10.21
alpha	3193750	Emission	419848.993
beta	55186.69		
F	81066956	Aquaculture Profit	1030805476
I	1400804		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
		Revenue	0
P	0	Abatement Cost	0
Q	0	T	0
alpha	0	Emission	0
beta	0		
F	0	Factory Profit	0
I	0		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	1,030,805,475.72	Uniform Tax	10.21
Transfer coefficient	-		
Subbasin Emission	419,848.94		
At-1	353,366.59		
A	419,848.94		
A'	420,241.15	Emission Pass	Approve

Pig Farm Sector

Constant			
		Revenue	0
P	0	Abatement Cost	0
Q	0	T	0
alpha	0	Emission	0
beta	0		
F	0	Pig Farm Profit	0
I	0		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
		Revenue	0
P	0	Abatement Cost	0
Q	0	T	0
alpha	0	Emission	0
beta	0		
F	0	Urban Profit	0
I	0		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
		Revenue	1408819958
P	55502500	Abatement Cost	373727824
Q	25.383	T	10.21
alpha	3193750	Emission	419848.942
beta	55186.69		
F	81066956	Aquaculture Profit	1030805476
I	1400804		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
		Revenue	0
P	0	Abatement Cost	0
Q	0	T	0
alpha	0	Emission	0
beta	0		
F	0	Factory Profit	0
I	0		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-7: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin RFm

Subbasin Profit	12320342050		
Transfer coefficient	0		
Subbasin Emission	2777309.128		
At-1	419848.9926		
A	2777309.128		
A'	2,787,159.76	Emission Pass	Approve

Pig Farm Sector

Constant			
		Revenue	42681357
P	587	Abatement Cost	813051.106
Q	72711	T	0.38
alpha	5.53	Emission	292070.654
beta	13.6		
F	402091.83	Pig Farm Profit	41757319
I	988869.6		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.136506		
e^a	0.3057645		

Urban Community Sector

Constant			
		Revenue	11173465.5
P	0	Abatement Cost	1011631.32
Q	48806	T	6.42
alpha	27.75382	Emission	44008.6812
beta	3.006664		
F	1354553	Urban Profit	9879298.42
I	146743.3		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
		Revenue	7688317305
P	55502500	Abatement Cost	1200458463
Q	138.522	T	10.11
alpha	1859804.5	Emission	1361943.8
beta	32788.411		
F	257623844	Aquaculture Profit	6474089590
I	4541916.3		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.625506		

Factory Sector

Constant			
		Revenue	5798532010
P	-	Abatement Cost	2782917.41
Q	325375.6	T	1.05
alpha	9.558863	Emission	1079286
beta	11.1041		
F	3110221	Factory Profit	5794615843
I	3613003		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	12,325,327,989.60	Uniform Tax	5.73		
Transfer coefficient	-				
Subbasin Emission	2,785,689.95				
At-1	419,848.94				
A	2,785,689.95				
A'	2,787,159.76			Emission Pass	Approve

Pig Farm Sector

Constant			
		Revenue	42681357
P	587	Abatement Cost	1126296.33
Q	72711	T	5.73
alpha	5.53	Emission	26031.7096
beta	13.6		
F	402091.83	Pig Farm Profit	41401315
I	988869.6		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.136506		
e^a	0.3057645		

Urban Community Sector

Constant			
		Revenue	11173465.5
P	0	Abatement Cost	986820.066
Q	48806	T	5.73
alpha	27.75382	Emission	40099.199
beta	3.006664		
F	1354553	Urban Profit	9911028
I	146743.3		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
		Revenue	7688317305
P	55502500	Abatement Cost	1192753637
Q	138.522	T	5.73
alpha	1859804.5	Emission	2387587.86
beta	32788.411		
F	257623844	Aquaculture Profit	6481882789
I	4541916.3		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.625506		

Factory Sector

Constant			
		Revenue	5798532010
P	-	Abatement Cost	4547382.19
Q	325375.6	T	5.73
alpha	9.558863	Emission	323171.10
beta	11.1041		
F	3110221	Factory Profit	5792132857
I	3613003		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-8: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin LP

Subbasin Profit	5929363389
Transfer coefficient	0
Subbasin Emission	154432.288
At-1	2777309.13
A	154432.288
A'	154,830.30
Emission Pass	Approve

Pig Farm Sector

Constant			
P	587	Revenue	1350100
Q	2300	Abatement Cost	17063.158
alpha	5.475	T	0.19
beta	13.6875	Emission	12259.019
F	12592.5	Pig Farm Profit	1330707.6
I	31481.25		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
P	0	Revenue	2643154.95
Q	11705	Abatement Cost	113932.293
alpha	14.1707	T	4.43
beta	1.535159	Emission	7182.79618
F	165868	Urban Profit	2497402.87
I	17969.04		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	175221393
Q	3.157	Abatement Cost	47148460
alpha	3193750	T	7.51
beta	57031.25	Emission	72009.745
F	10082669	Aquaculture Profit	127532139
I	180047.7		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
P	-	Revenue	5798532010
Q	346093	Abatement Cost	375827.997
alpha	1.339211	T	2.43
beta	0.455305	Emission	62980.728
F	463491.6	Factory Profit	5798003139
I	157577.8		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	5,929,457,591.33	Uniform Tax	4.93
Transfer coefficient	-		
Subbasin Emission	154,572.92		
At-1	2,785,689.95		
A	154,572.92		
A'	154,830.30	Emission Pass	Approve

Pig Farm Sector

Constant			
P	587	Revenue	1350100
Q	2300	Abatement Cost	25229.372
alpha	5.475	T	4.93
beta	13.6875	Emission	698.56973
F	12592.5	Pig Farm Profit	1321426.7
I	31481.25		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
P	0	Revenue	2643154.95
Q	11705	Abatement Cost	116623.763
alpha	14.1707	T	4.93
beta	1.535159	Emission	6606.72211
F	165868	Urban Profit	2493960.05
I	17969.04		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	175221393
Q	3.157	Abatement Cost	46923960
alpha	3193750	T	4.93
beta	57031.25	Emission	109171.9
F	10082669	Aquaculture Profit	127759215
I	180047.7		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
P	-	Revenue	5798532010
Q	346093	Abatement Cost	461208.577
alpha	1.339211	T	4.93
beta	0.455305	Emission	38095.7304
F	463491.6	Factory Profit	5797882990
I	157577.8		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-9: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin RG

Subbasin Profit	6539616025
Transfer coefficient	0
Subbasin Emission	2427598.635
At-1	154432.288
A	2427598.635
A'	2,449,402.78
Emission Pass	Approve

Pig Farm Sector

Constant			
P	587	Revenue	85861664
Q	146272	Abatement Cost	1699788.51
alpha	5.5490121	T	0.3
beta	13.576482	Emission	773438.037
F	811665.1		
I	1985859.2	Pig Farm Profit	83929844.1
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.136506		
e^a	0.3057645		

Urban Community Sector

Constant			
P	0	Revenue	3613478.47
Q	16002	Abatement Cost	200908.755
alpha	18.2563	T	4.44
beta	1.977766	Emission	12637.6506
F	292137.3		
I	31648.2	Urban Profit	3356458.55
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	2223374648
Q	40.059	Abatement Cost	598264234
alpha	3193750	T	7.51
beta	57031.25	Emission	913726.697
F	127938431		
I	2284614.8	Aquaculture Profit	1618248326
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.625506		

Factory Sector

Constant			
P	-	Revenue	4837476702
Q	404836.1	Abatement Cost	2412780.7
alpha	6.708389	T	1.35
beta	4.499067	Emission	727796.251
F	2715798		
I	1821385	Factory Profit	4834081396
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	6,543,201,858.51	Uniform Tax	3.46
Transfer coefficient	-		
Subbasin Emission	2,444,084.07		
At-1	154,572.92		
A	2,444,084.07		
A'	2,449,402.78	Emission Pass	Approve

Pig Farm Sector

Constant			
P	587	Revenue	85861664
Q	146272	Abatement Cost	2280061.46
alpha	5.5490121	T	3.46
beta	13.576482	Emission	89954.3499
F	811665.1		
I	1985859.2	Pig Farm Profit	83270360.5
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.136506		
e^a	0.3057645		

Urban Community Sector

Constant			
P	0	Revenue	3613478.47
Q	16002	Abatement Cost	190262.18
alpha	18.2563	T	3.46
beta	1.977766	Emission	15357.9534
F	292137.3		
I	31648.2	Urban Profit	3370077.78
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	2223374648
Q	40.059	Abatement Cost	593029679
alpha	3193750	T	3.46
beta	57031.25	Emission	1965909.69
F	127938431		
I	2284614.8	Aquaculture Profit	1623542921
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.625506		

Factory Sector

Constant			
P	-	Revenue	4837476702
Q	404836.1	Abatement Cost	3168099.04
alpha	6.708389	T	3.46
beta	4.499067	Emission	372862.079
F	2715798		
I	1821385	Factory Profit	4833018500
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-10: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin LQ

Subbasin Profit	462160160		
Transfer coefficient	0		
Subbasin Emission	8745.255		
At-1	2427598.6		
A	8745.255		
A'	8,746.01	Emission Pass	Approve

Pig Farm Sector			
Constant		Revenue	3111100
P	587	Abatement Cost	58291.08
Q	5300	T	2.16
alpha	5.618245	Emission	3683.84
beta	13.90237		
F	29776.7	Pig Farm Profit	3044852
I	73682.55		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector			
Constant		Revenue	2033230.9
P	0	Abatement Cost	424239.35
Q	9004	T	63.37
alpha	38.33775	Emission	1869.7248
beta	4.153257		
F	345193.1	Urban Profit	1490507
I	37395.92		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector			
Constant		Revenue	50895793
P	55502500	Abatement Cost	14025576
Q	0.917	T	61.53
alpha	3193750	Emission	2614.55
beta	57031.25		
F	2928669	Aquaculture Profit	36709343
I	52297.66		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector			
Constant		Revenue	420964441
P	-	Abatement Cost	34808.384
Q	8387.7	T	24.56
alpha	3.407206	Emission	577.13969
beta	1.37631		
F	28578.62	Factory Profit	420915458
I	11544.07		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	462,301,612.68	Uniform Tax	33.05	
Transfer coefficient	-			
Subbasin Emission	8,744.92			
At-1	2,444,084.07			
A	8,744.92			
A'	8,746.01		Emission Pass	Approve

Pig Farm Sector			
Constant		Revenue	3111100
P	587	Abatement Cost	80890.76
Q	5300	T	33.05
alpha	5.618245	Emission	334.1021
beta	13.90237		
F	29776.7	Pig Farm Profit	3019167
I	73682.55		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector			
Constant		Revenue	2033230.9
P	0	Abatement Cost	368036.35
Q	9004	T	33.05
alpha	38.33775	Emission	3110.0677
beta	4.153257		
F	345193.1	Urban Profit	1562406.8
I	37395.92		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector			
Constant		Revenue	50895793
P	55502500	Abatement Cost	13927074
Q	0.917	T	33.05
alpha	3193750	Emission	4833.388
beta	57031.25		
F	2928669	Aquaculture Profit	36808975
I	52297.66		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector			
Constant		Revenue	420964441
P	-	Abatement Cost	37931.229
Q	8387.7	T	33.05
alpha	3.407206	Emission	467.35998
beta	1.37631		
F	28578.62	Factory Profit	420911063
I	11544.07		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-11: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin RH

Subbasin Profit	29768358934
Transfer coefficient	0
Subbasin Emission	1490960.848
At-1	8745.254954
A	1490960.848
A'	1,491,139.85
Emission Pass	Approve

Pig Farm Sector			
Constant		Revenue	160103663
P	587	Abatement Cost	4223481.1
Q	272749	T	3.33
alpha	5.299371	Emission	172943.34
beta	12.6815		
F	1445398	Pig Farm Profit	155304281
I	3458867		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector			
Constant		Revenue	38923016.43
P	0	Abatement Cost	23477529.85
Q	171266	T	43.99
alpha	101.3766	Emission	149055.7772
beta	17.40665		
F	17362363	Urban Profit	8888522.941
I	2981167		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector			
Constant		Revenue	263803383
P	55502500	Abatement Cost	72697450
Q	4.753	T	61.53
alpha	3193750	Emission	13551.744
beta	57031.25		
F	15179894	Aquaculture Profit	190272093
I	271069.5		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector			
Constant		Revenue	29533795937
P	-	Abatement Cost	85204938.12
Q	3254048	T	30.03
alpha	9.253179	Emission	1155409.985
beta	7.102444		
F	30110287	Factory Profit	29413894037
I	23111694		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	29,773,150,944.87	Uniform Tax	27.79
Transfer coefficient	-		
Subbasin Emission	1,490,778.70		
At-1	8,744.92		
A	1,490,778.70		
A'	1,491,139.85	Emission Pass	Approve

Pig Farm Sector			
Constant		Revenue	160103663
P	587	Abatement Cost	5448646
Q	272749	T	27.79
alpha	5.299371	Emission	26763.995
beta	12.6815		
F	1445398	Pig Farm Profit	153911246
I	3458867		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector			
Constant		Revenue	38923016.43
P	0	Abatement Cost	21237635.9
Q	171266	T	27.79
alpha	101.3766	Emission	213436.2109
beta	17.40665		
F	17362363	Urban Profit	11753988.23
I	2981167		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector			
Constant		Revenue	263803383
P	55502500	Abatement Cost	72045134
Q	4.753	T	27.79
alpha	3193750	Emission	29735.778
beta	57031.25		
F	15179894	Aquaculture Profit	190931892
I	271069.5		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector			
Constant		Revenue	29533795937
P	-	Abatement Cost	83314898.29
Q	3254048	T	27.79
alpha	9.253179	Emission	1220842.718
beta	7.102444		
F	30110287	Factory Profit	29416553819
I	23111694		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-12: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin RI

Subbasin Profit	56714895297
Transfer coefficient	0
Subbasin Emission	34733722.14
At-1	1490960.848
A	34733722.14
A'	36,703,767.54
Emission Pass	Approve

Pig Farm Sector

	Constant		
		Revenue	37103683
P	587	Abatement Cost	605284.261
Q	63209	T	0.15
alpha	5.4374658	Emission	550828.186
beta	13.033452		
F	343696.78	Pig Farm Profit	36415774.5
I	823831.46		
	Co-effcient		
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.136506		
e^a	0.3057645		

Urban Community Sector

	Constant		
		Revenue	45407952.86
P	0	Abatement Cost	3816552.775
Q	209526	T	2.13
alpha	30.61558	Emission	500428.9967
beta	3.421803		
F	6414760	Urban Profit	40525486.32
I	716956.6		
	Co-effcient		
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

	Constant		
		Revenue	3415851410
P	55502500	Abatement Cost	913268905
Q	61.5441	T	4.27
alpha	3193750	Emission	2453207.25
beta	57031.25		
F	196556469	Aquaculture Profit	2492107311
I	3509937		
	Co-effcient		
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.625506		

Factory Sector

	Constant		
		Revenue	54158796949
P	-	Abatement Cost	9202713.134
Q	4134001	T	0.12
alpha	3.519481	Emission	31229257.71
beta	11.46183		
F	14549538	Factory Profit	54145846725
I	47383229		
	Co-effcient		
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	56,730,056,541.02	Uniform Tax	0.12
Transfer coefficient	-		
Subbasin Emission	36,126,427.70		
At-1	1,490,778.70		
A	36,126,427.70		
A'	36,703,767.54		
Emission Pass	Approve		

Pig Farm Sector

	Constant		
		Revenue	37103683
P	587	Abatement Cost	589275.37
Q	63209	T	0.12
alpha	5.4374658	Emission	670339.996
beta	13.033452		
F	343696.78	Pig Farm Profit	36433966.0
I	823831.46		
	Co-effcient		
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.136506		
e^a	0.3057645		

Urban Community Sector

	Constant		
		Revenue	45407952.86
P	0	Abatement Cost	3451918.205
Q	209526	T	0.12
alpha	30.61558	Emission	716956.5935
beta	3.421803		
F	6414760	Urban Profit	41069999.07
I	716956.6		
	Co-effcient		
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

	Constant		
		Revenue	3415851410
P	55502500	Abatement Cost	909524369
Q	61.5441	T	0.12
alpha	3193750	Emission	3509936.95
beta	57031.25		
F	196556469	Aquaculture Profit	2505905849
I	3509937		
	Co-effcient		
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.625506		

Factory Sector

	Constant		
		Revenue	54158796949
P	-	Abatement Cost	9202720.759
Q	4134001	T	0.12
alpha	3.519481	Emission	31229194.16
beta	11.46183		
F	14549538	Factory Profit	54145846725
I	47383229		
	Co-effcient		
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-13: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin LS

Subbasin Profit	3.06763E+11
Transfer coefficient	0
Subbasin Emission	34635332.28
At-1	5037226.181
A	34635332.28
A'	34,675,725.07
Emission Pass	Approve

Pig Farm Sector

Constant			
P	587	Revenue	30656075
Q	52225	Abatement Cost	509815.52
alpha	5.848876	T	0.13
beta	13.12669	Emission	514155.88
F	305457.6	Pig Farm Profit	30079419
I	685541.2		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
P	0	Revenue	20862973.86
Q	98663	Abatement Cost	3059630.416
alpha	52.97503	T	1.92
beta	6.029059	Emission	445059.7059
F	5226675	Urban Profit	16948828.81
I	594845		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	831316445
Q	14.978	Abatement Cost	226782530
alpha	3193750	T	3.91
beta	59312.5	Emission	665268.02
F	47835988	Aquaculture Profit	601932717
I	888382.6		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
P	-	Revenue	3.06198E+11
Q	11134486	Abatement Cost	59177136.5
alpha	5.156587	T	0.73
beta	3.957572	Emission	33010848.67
			0
F	57415944	Factory Profit	3.06114E+11
I	44065531		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	306,766,308,508.40	Uniform Tax	0.74
Transfer coefficient	-		
Subbasin Emission	34,291,368.25		
At-1	5,053,101.60		
A	34,291,368.25		
A'	34,675,725.07		
		Emission Pass	Approve

Pig Farm Sector

Constant			
P	587	Revenue	30656075
Q	52225	Abatement Cost	625166.59
alpha	5.848876	T	0.74
beta	13.12669	Emission	115389.36
F	305457.6	Pig Farm Profit	29945520
I	685541.2		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
P	0	Revenue	20862973.86
Q	98663	Abatement Cost	2821518.127
alpha	52.97503	T	0.74
beta	6.029059	Emission	594845.0087
F	5226675	Urban Profit	17601270.43
I	594845		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	831316445
Q	14.978	Abatement Cost	226031478
alpha	3193750	T	0.74
beta	59312.5	Emission	888382.63
F	47835988	Aquaculture Profit	604627564
I	888382.6		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
P	-	Revenue	3.06198E+11
Q	11134486	Abatement Cost	59410034.46
alpha	5.156587	T	0.74
beta	3.957572	Emission	32692751.25
F	57415944	Factory Profit	3.06114E+11
I	44065531		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-14: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin RJ

Subbasin Profit	25210498513
Transfer coefficient	0
Subbasin Emission	5037226.181
At-1	34733722.14
A	5037226.181
A'	5,064,448.14
Emission Pass	**Approve**

Pig Farm Sector

Constant			
P	587	**Revenue**	3665228
Q	6244	**Abatement Cost**	48221.6503
alpha	5.6702434	**T**	0.11
beta	13.394635	**Emission**	59843.0542
F	35405	**Pig Farm Profit**	3610423.61
I	83636.1		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.136506		
e^a	0.3057645		

Urban Community Sector

Constant			
P	0	**Revenue**	12961700.77
Q	61179	**Abatement Cost**	984669.2258
alpha	27.39997	**T**	1.86
beta	3.21609	**Emission**	147567.8618
F	1676303	**Urban Profit**	11702555.32
I	196757.1		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	**Revenue**	2123747660
Q	38.264	**Abatement Cost**	570648432
alpha	3193750	**T**	3.96
beta	57653.013	**Emission**	1652862.84
F	122205650	**Aquaculture Profit**	1546553891
I	2206034.9		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.625506		

Factory Sector

Constant			
P	-	**Revenue**	23654889435
Q	613674.5	**Abatement Cost**	4446928.854
alpha	9.586287	**T**	0.57
beta	6.951844	**Emission**	3176952.423
F	5882860	**Factory Profit**	23648631643
I	4266169		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	25,216,997,645.26	**Uniform Tax**	0.74
Transfer coefficient	-		
Subbasin Emission	5,053,101.60		
At-1	36,126,427.70		
A	5,053,101.60		
A'	5,064,448.14		
Emission Pass	**Approve**		

Pig Farm Sector

Constant			
P	587	**Revenue**	3665228
Q	6244	**Abatement Cost**	60627.97
alpha	5.6702434	**T**	0.74
beta	13.394635	**Emission**	11184.4296
F	35405	**Pig Farm Profit**	3596323.55
I	83636.1		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.136506		
e^a	0.3057645		

Urban Community Sector

Constant			
P	0	**Revenue**	12961700.77
Q	61179	**Abatement Cost**	908649.9354
alpha	27.39997	**T**	0.74
beta	3.21609	**Emission**	196757.1491
F	1676303	**Urban Profit**	11907450.54
I	196757.1		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	**Revenue**	2123747660
Q	38.264	**Abatement Cost**	568761997
alpha	3193750	**T**	0.74
beta	57653.013	**Emission**	2206034.91
F	122205650	**Aquaculture Profit**	1553353197
I	2206034.9		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.625506		

Factory Sector

Constant			
P	-	**Revenue**	23654889435
Q	613674.5	**Abatement Cost**	4795808.228
alpha	9.586287	**T**	0.74
beta	6.951844	**Emission**	2639125.115
F	5882860	**Factory Profit**	23648140674
I	4266169		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-15: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin RK

Subbasin Profit	4890386601		
Transfer coefficient	0		
Subbasin Emission	3646479.49		
At-1	34635332.28		
A	3646479.49		
A'	3,653,191.05	Emission Pass	Approve

Pig Farm Sector

Constant			
		Revenue	569390
P	587	Abatement Cost	6235.48072
Q	970	T	0.09
alpha	5.94	Emission	9442.95
beta	12.98		
F	5761.8	Pig Farm Profit	562304.654
I	12590.6		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.136506		
e^a	0.3057645		

Urban Community Sector

Constant			
		Revenue	8427918.52
P	0	Abatement Cost	713712.34
Q	41373	T	1.99
alpha	29.83258	Emission	100173.189
beta	3.231863		0
F	1234263	Urban Profit	7514861.54
I	133711.9		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
		Revenue	3432330103
P	55502500	Abatement Cost	936336705
Q	61.841	T	3.91
alpha	3193750	Emission	2746875.51
beta	59312.5		
F	197504694	Aquaculture Profit	2485253115
I	3667944.3		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.625506		

Factory Sector

Constant			
		Revenue	2400331774
P	-	Abatement Cost	2327468.54
Q	202907.2	T	1.2
alpha	14.28067	Emission	789987.842
beta	5.207676		
F	2897650	Factory Profit	2397056320
I	1056675		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	4,890,798,383.33	Uniform Tax	3.35
Transfer coefficient	-		
Subbasin Emission	3,648,165.89		
At-1	34,291,368.25		
A	3,648,165.89		
A'	3,653,191.05	Emission Pass	Approve

Pig Farm Sector

Constant			
		Revenue	569390
P	587	Abatement Cost	9626.09156
Q	970	T	3.35
alpha	5.94	Emission	392.310206
beta	12.98		
F	5761.8	Pig Farm Profit	558449.669
I	12590.6		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.136506		
e^a	0.3057645		

Urban Community Sector

Constant			
		Revenue	8427918.52
P	0	Abatement Cost	799670.096
Q	41373	T	3.35
alpha	29.83258	Emission	66667.8942
beta	3.231863		
F	1234263	Urban Profit	7404910.98
I	133711.9		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
		Revenue	3432330103
P	55502500	Abatement Cost	934697344
Q	61.841	T	3.35
alpha	3193750	Emission	3200290.68
beta	59312.5		
F	197504694	Aquaculture Profit	2486911785
I	3667944.3		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.625506		

Factory Sector

Constant			
		Revenue	2400331774
P	-	Abatement Cost	3132805.82
Q	202907.2	T	3.35
alpha	14.28067	Emission	380815.002
beta	5.207676		
F	2897650	Factory Profit	2395923238
I	1056675		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-16: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin LT

Subbasin Profit	69813946413
Transfer coefficient	0
Subbasin Emission	35562136.68
At-1	3646479.49
A	35562136.68
A'	36,020,934.17
Emission Pass	Approve

Pig Farm Sector

Constant			
		Revenue	0
P	0	Abatement Cost	0
Q	0	T	0
alpha	0	Emission	0
beta	0		
F	0	Pig Farm Profit	0
I	0		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.136506		
e^a	0.3057645		

Urban Community Sector

Constant			
		Revenue	13227414.33
P	0	Abatement Cost	279650.5512
Q	64496	T	1.88
alpha	7.4099167	Emission	41543.98483
beta	0.8600257		
F	477909.99	Urban Profit	12869661.09
I	55468.218		
Co-effcient			
a	-0.221105		
b	0.808064		
c	0.472857		
d	-0.279287		
e^a	0.8016325		

Aquaculture Sector

Constant			
		Revenue	8325375
P	55502500	Abatement Cost	2271156
Q	0.15	T	3.91
alpha	3193750	Emission	6662.47
beta	59312.5		
F	479062.5	Aquaculture Profit	6028168
I	8896.875		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.625506		

Factory Sector

Constant			
		Revenue	69844138682
P	-	Abatement Cost	34884525.61
Q	2832093.4	T	0.4
alpha	13.982542	Emission	35513930.23
beta	16.935722		
F	39599864	Factory Profit	69795048584
I	47963547		
Co-effcient			
a	-2.706499		
b	1.381092		
c	0.169197		
d	-0.407217		
e^a	0.0667702		

Subbasin Profit	69,814,054,030.76	Uniform Tax	0.4
Transfer coefficient	-		
Subbasin Emission	35,578,297.18		
At-1	3,648,165.89		
A	35,578,297.18		
A'	36,020,934.17	Emission Pass	Approve

Pig Farm Sector

Constant			
		Revenue	0
P	0	Abatement Cost	0
Q	0	T	0
alpha	0	Emission	0
beta	0		
F	0	Pig Farm Profit	0
I	0		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
		Revenue	13227414.33
P	0	Abatement Cost	257961.6163
Q	64496	T	0.4
alpha	7.409917	Emission	55468.21792
beta	0.860026		
F	477910	Urban Profit	12947265.43
I	55468.22		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
		Revenue	8325375
P	55502500	Abatement Cost	2263635
Q	0.15	T	0.4
alpha	3193750	Emission	8896.875
beta	59312.5		
F	479062.5	Aquaculture Profit	6058181
I	8896.875		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
		Revenue	69844138682
P	-	Abatement Cost	34884524.86
Q	2832093	T	0.4
alpha	13.98254	Emission	35513932.09
beta	16.93572		
F	39599864	Factory Profit	69795048584
I	47963547		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-17: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin LU

Subbasin Profit	38297405195
Transfer coefficient	0
Subbasin Emission	16946234.38
At-1	35562136.68
A	16946234.38
A'	17,164,785.07
Emission Pass	Approve

Pig Farm Sector

Constant			
P	0	Revenue	0
Q	0	Abatement Cost	0
alpha	0	T	0
beta	0	Emission	0
F	0	Pig Farm Profit	0
I	0		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
P	0	Revenue	12316254.12
Q	60461	Abatement Cost	2901901.437
alpha	81.15806	T	1.84
beta	9.738967	Emission	440469.0935
F	4906897	Urban Profit	8603889.553
I	588827.7		0
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	7020455723
Q	126.489	Abatement Cost	280563515
alpha	467868.3	T	3.91
beta	8688.982	Emission	823034.034
F	59180188	Aquaculture Profit	6736674144
I	1099061		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
P	-	Revenue	31575430892
Q	1941030	Abatement Cost	16560156.21
alpha	10.33128	T	0.43
beta	10.92126	Emission	15682731.26
F	20053326	Factory Profit	31552127161
I	21198492		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	38,301,680,854.55	Uniform Tax	0.44
Transfer coefficient	-		
Subbasin Emission	17,116,499.53		
At-1	35,578,207.18		
A	17,116,499.53		
A'	17,164,785.07		
		Emission Pass	Approve

Pig Farm Sector

Constant			
P	0	Revenue	0
Q	0	Abatement Cost	0
alpha	0	T	0
beta	0	Emission	0
F	0	Pig Farm Profit	0
I	0		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.13651		
e^a	0.305765		

Urban Community Sector

Constant			
P	0	Revenue	12316254.12
Q	60461	Abatement Cost	2675914.129
alpha	81.15806	T	0.44
beta	9.738967	Emission	596827.6669
F	4906897	Urban Profit	9381255.82
I	588827.7		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
P	55502500	Revenue	7020455723
Q	126.489	Abatement Cost	279634350
alpha	467868.3	T	0.44
beta	8688.982	Emission	1099060.63
F	59180188	Aquaculture Profit	6740337786
I	1099061		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.62551		

Factory Sector

Constant			
P	-	Revenue	31575430892
Q	1941030	Abatement Cost	16670690.11
alpha	10.33128	T	0.44
beta	10.92126	Emission	15420611.24
F	20053326	Factory Profit	31551971613
I	21198492		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Table C-18: Mathematical Decision-making model of Non-uniform and Uniform tax in sub-basin RL

Subbasin Profit	69491085532		
Transfer coefficient	0		
Subbasin Emission	32737500.14		
At-1	16946234.38		
A	32737500.14		
A'	33,193,053.54	Emission Pass	Approve

Pig Farm Sector

Constant			
		Revenue	88050
P	587	Abatement Cost	863.416418
Q	150	T	0.1
alpha	7.3	Emission	1180.71969
beta	10.95		
F	1095	Pig Farm Profit	87068.5116
I	1642.5		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.136506		
e^a	0.3057645		

Urban Community Sector

Constant			
		Revenue	20179296.57
P	0	Abatement Cost	673508.1026
Q	99061	T	1.9
alpha	11.61593	Emission	99001.05162
beta	1.336702		
F	1150686	Urban Profit	19317686.46
I	132415		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
		Revenue	6049383983
P	55502500	Abatement Cost	1460550376
Q	108.993	T	3.91
alpha	2826591.7	Emission	4284528.24
beta	52493.845		
F	308078706	Aquaculture Profit	4572081101
I	5721461.7		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.625506		

Factory Sector

Constant			
		Revenue	64926053872
P	-	Abatement Cost	18798942.8
Q	7095279	T	0.27
alpha	3.430088	Emission	28352790.12
beta	5.412315		
F	24337434	Factory Profit	64899599675
I	38401886		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

Subbasin Profit	69,510,665,220.78	Uniform Tax	0.29
Transfer coefficient	-		
Subbasin Emission	32,803,314.06		
At-1	17,116,499.53		
A	32,803,314.06		
A'	33,193,053.54	Emission Pass	Approve

Pig Farm Sector

Constant			
		Revenue	88050
P	587	Abatement Cost	977.599006
Q	150	T	0.29
alpha	7.3	Emission	475.330907
beta	10.95		
F	1095	Pig Farm Profit	86934.555
I	1642.5		
Co-effcient			
a	-1.18494		
b	0.719655		
c	0.523361		
d	-0.136506		
e^a	0.3057645		

Urban Community Sector

Constant			
		Revenue	20179296.57
P	0	Abatement Cost	620968.5291
Q	99061	T	0.29
alpha	11.61593	Emission	132415.0205
beta	1.336702		
F	1150686	Urban Profit	19519927.68
I	132415		
Co-effcient			
a	-0.22111		
b	0.808064		
c	0.472857		
d	-0.27929		
e^a	0.801633		

Aquaculture Sector

Constant			
		Revenue	6049383983
P	55502500	Abatement Cost	1455713344
Q	108.993	T	0.29
alpha	2826591.7	Emission	5721461.69
beta	52493.845		
F	308078706	Aquaculture Profit	4592011414
I	5721461.7		
Co-effcient			
a	3.679473		
b	0.466506		
c	0.544964		
d	-0.01147		
e^a	39.625506		

Factory Sector

Constant			
		Revenue	64926053872
P	-	Abatement Cost	19191728.57
Q	7095279	T	0.29
alpha	3.430088	Emission	26948962.02
beta	5.412315		
F	24337434	Factory Profit	64899046944
I	38401886		
Co-effcient			
a	-2.7065		
b	1.381092		
c	0.169197		
d	-0.40722		
e^a	0.06677		

BIOGRAPHY

Mr. Rachasak Klayklung was born on June 08, 1977 in Chonburi, Thailand. He attended Triamudomsuksa School in Bangkok and graduated in 1994. He received his Bachelor's Degree in Computer Science from Faculty of Science, Thammasat University and Master's Degree in Environmental and Natural Resources in Economics from Faculty of Economics, Chulalongkorn University in 1999 and 2000, respectively. After that, he pursued his Philosophy of Doctoral Degree studies in the International Postgraduate Programs in Environmental Management, Inter-Department of Environmental Management, Chulalongkorn University, Bangkok, Thailand in April 2002.