การเลือกพื้นที่ศักยภาพเพื่อเป็นแหล่งกำจัดขยะมูลฝอยในจังหวัดปทุมธานี

นางสาว กมลพร เกิดพุฒ

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SELECTION OF POTENTIAL SOLID WASTE DISPOSAL AREAS IN PATHUM THANI PROVINCE

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for the Degree of Master of Science in Environmental Science

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กมลพร เกิดพุฒ : การเลือกพื้นที่ศักยภาพเพื่อเป็นแหล่งกำจัดขยะมูลฝอยในจังหวัดปทุมธานี (SELECTION OF POTENTIAL SOLID WASTE DISPOSAL AREAS IN PATHUM THANI PROVINCE) อ. ที่ปรึกษา : รศ. ดร. ชัยยุทธ ขันทปราบ , 108 หน้า. ISBN 974-334-726-7

การศึกษาในครั้งนี้เป็นการนำระบบสารสนเทศทางภูมิศาสตร์ (GIS) มาประยุกต์ใช้หาพื้นที่ศักยภาพเพื่อเป็นแหล่งกำจัดขยะมูลฝอยอย่างถูกสุขลักษณะให้กับจังหวัดปทุมธานีซึ่งมีพื้นที่ประมาณ 1,500 ตารางกิโลเมตร โดยการนำปัจจัยทางสิ่งแวดล้อมบางประการที่สัมพันธ์กับการหาพื้นที่ฝังกลบขยะ ได้แก่ สภาพภูมิอากาศ น้ำผิวดิน ปริมาณน้ำใต้ดิน ความเหมาะสมของดิน ธรณีวิทยา การใช้ประโยชน์ที่ดิน เส้นทางการคมนาคม ขอบเขตการปกครอง และ สภาพทางเศรษฐกิจและสังคม มาประกอบการพิจารณาด้วยการใช้เทคนิคการซ้อนทับของข้อมูลแผนที่ ระบบการให้ค่าน้ำหนักของปัจจัย ภายใต้โปรแกรม Arc/Info และ Arc/View ในการวิเคราะห์และแสดงผลของการศึกษา

ผลการศึกษาที่ได้จะมีการแบ่งพื้นที่ศักยภาพในการเป็นแหล่งกำจัดขยะมูลฝอยอย่างถูกสุขลักษณะเป็น 5 ระดับความเหมาะสมคือ เหมาะสมมากที่สุด เหมาะสม เหมาะสมปานกลาง เหมาะสมน้อย และไม่เหมาะสม โดยพื้นที่ที่มีความเหมาะสม และพื้นที่ที่มีความเหมาะสมมากที่สุด ส่วนใหญ่จะพบในอำเภอหนองเสือ รองลงมาคือ อำเภอสามโคก อำเภอลำลูกกา และอำเภอคลองหลวง ตามลำดับ ซึ่งพื้นที่ที่มีขนาดใหญ่และต่อเนื่องมีพื้นที่มากกว่า 1 ตารางกิโลเมตร ส่วนพื้นที่ที่มีระดับความเหมาะสมปานกลางจะพบพื้นที่ที่ต่อเนื่องขนาดใหญ่ โดยจะพบมากในอำเภอลำลูกกา อำเภอคลองหลวง อำเภอเมือง และอำเภอสามโคกตามลำดับ ส่วนพื้นที่ที่มีความเหมาะสมน้อยและพื้นที่ที่ไม่มีความเหมาะสมนั้นพบได้น้อยในพื้นที่ศึกษา ซึ่งส่วนใหญ่มีพื้นที่น้อยกว่า 1 ตารางกิโลเมตร ถ้ามีการเลือกพื้นที่ที่มีความเหมาะสมมากที่สุดมาใช้ฝังกลบขยะมูลฝอยพบว่าจะมีต้นทุนด้านที่ดินประมาณ 125-250 ล้านบาทต่อพื้นที่ 1 ตารางกิโลเมตร

สหสาขา วิทยาศาสตร์สภาวะแวดล้อม ลายมือชื่อนิสิต ____________

สาขาวิชา วิทยาศาสตร์สภาวะแวดล้อม

ปีการศึกษา 2542 ลายมือชื่ออาจารย์ที่ปรึกษา ____________

4072201823 :MAJOR IN INTER-DEPARTMENT OF ENVIRONMENTAL SCIENCE
KEY WORD : SOLID WASTE DISPOSAL AREA / SANITARY LANDFILL / AREA SELECTION / GIS

KAMOLPORN KERDPUT : SELECTION OF POTENTIAL SOLID WASTE DISPOSAL AREAS IN PATHUM THANI PROVINCE. THESIS ADVISOR : ASSOCIATE PROFESSOR CHAIYUDH KHANTAPRAB, Ph.D. 108 pp. ISBN 974-334-726-7

The potential areas selection for sanitary landfill of the area under the present study covers approximately 1,500 square kilometers of Pathum Thani province, in the lower part of central Thailand. Selected environmental factors related to the solid waste disposal site, namely, climate, surface water, groundwater, soil suitability, geology, land use, transportation, administration and socio-economic conditions are employed in the consideration using the Geographic Information System (GIS) as a tool. The overlay technique and weight rating system are taken into consideration under this study. Arc/Info and Arc/View programs are used as a tool for overlay mapping and weight rating system.

The findings of suitable areas for sanitary landfill are classified into 5 classes, notably; most suitable , suitable , moderately suitable , less suitable , and unsuitable. The most suitable and suitable area are mainly located in Amphoe Nuangsua and some parts of Amphoe Samkhok, Amphoe Lumlukka and Amphoe Khlong Luang. The most suitable areas always appear as a large piece of land larger than 1 square kilometer. The large moderately suitable areas are located in Amphoe Lumlukka, Amphoe Khlong Luang, Amphoe Muang, and Amphoe Samkhok, respectively in decreasing size of the land. The less suitable and unsuitable areas are rarely found in the study area. The areas of these 2 classes are always smaller than 1 square kilometer. The land price is also brought into consideration for determining the possible landfill site. The capital cost of most suitable area for the sanitary landfill is about 125-250 million baht per 1 square kilometer.

สหสาขา วิทยาศาสตร์สภาวะแวดล้อม ลายมือชื่อนิสิต Kamolporn Kerdput

สาขาวิชา วิทยาศาสตร์สภาวะแวดล้อม

ปีการศึกษา 2542 ลายมือชื่ออาจารย์ที่ปรึกษา Ch. Khantap

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Finally, the author's lovely family has given cares, encouragement, and support throughout the study period.

CONTENTS

CONTENTS (cont.)

CONTENTS (cont.)

LIST OF TABLES

LIST OF TABLES (cont.)

LIST OF FIGURES

LIST OF FIGURES (cont.)

LIST OF FIGURES (cont.)

CHAPTER 1

INTRODUCTION

Environmental problems are now becoming the serious problems of urban areas as a result of population growth, human activities, city development, industrial expansion, etc. One of the major environmental problems encountered in many cities is solid waste management, particularly the solid waste disposal system. The role of urban planning should, therefore, include preventing and solving this problem.

In municipalities and sanitary districts, the solid waste management is under the responsibility of the Department of Local Administration, Ministry of Interior. To accomplish the environmental protection, waste disposal must demonstrate fundamental principles of sanitation which are not harmful to human's health and overall environment.

The Office of the National Economic and Social Development Board has studied solid waste disposal methods in municipalities of Thailand in B.E. 2533 (1990) and reported that 81.12% of urban wastes were disposed by open dumping, 7.55% employed the sanitary landfill and the rest (11.33%) was managed by composting, incineration, sea dumping, etc. In Thailand, dumping on land is the major practice method of disposal which brings about environmental problems to public health and quality of life.

Different methods of solid waste disposal produce effects on air and water quality, land use, public health and the overall environment particularly their leachate which frequently is above the effluent standards of the World Health Organization (WHO) and the Ministry of Industry of Thailand. Leachate is in liquid form after rain, surface water and groundwater may pass through a disposal site and dissolve suspended matter and organic wastes. The leachate can contaminates to surface water system and groundwater system.

Leachate from solid wastes causes nuisance and hazard to public health, especially if it contaminates to the groundwater, subsurface water, other watersupply sources and soils. Besides, each solid waste disposal site supports the breeding of rodents, rats, insects, cockroaches and flies. Air pollution, nuisance of odor, dust and ash, and visual pollution are all environmental effects.

The importance of solid waste management problems has been earlier pointed out. As a result, the planning of solid wastes management in the vicinity of every urban area has been expected in the future. This is basically due to the rapid population growth, changing of the life style, changing of the socio-economic conditions of the urban area, and expansion of the urban area. These factors have resulted in the increasing quantity of solid wastes and the requirement of expanding solid waste disposal sites.

The lack of appropriate and adequate area for disposal site is thus a problem. The selection and preparation of waste disposal site should be included in development planning of each developing city or urban area in order to minimize the environmental implications in the future.

So far, waste disposal site of each municipality or urban area has not been located with the awareness of environmental impacts and pollution problems. Therefore, most municipalities and urban areas are now facing with problems, particularly those caused by the leachate from the solid waste dumping.

1.1 The Study Area

Pathum Thani province is the growth corridor to be developed for Bangkok metropolis. The Development Plan of Great Bangkok has put the emphasis roles of Pathum Thani province to be the residential and industrial functions. Changing pattern of landuse from agricultural to industrial or residential has certainly promote the migration of people to live and work in Pathum Thani. The density of population in Pathum Thani is progressively and consequently causes the increasing generation of solid waste quantity and changing in the characteristics of solid wastes according to the new life style.

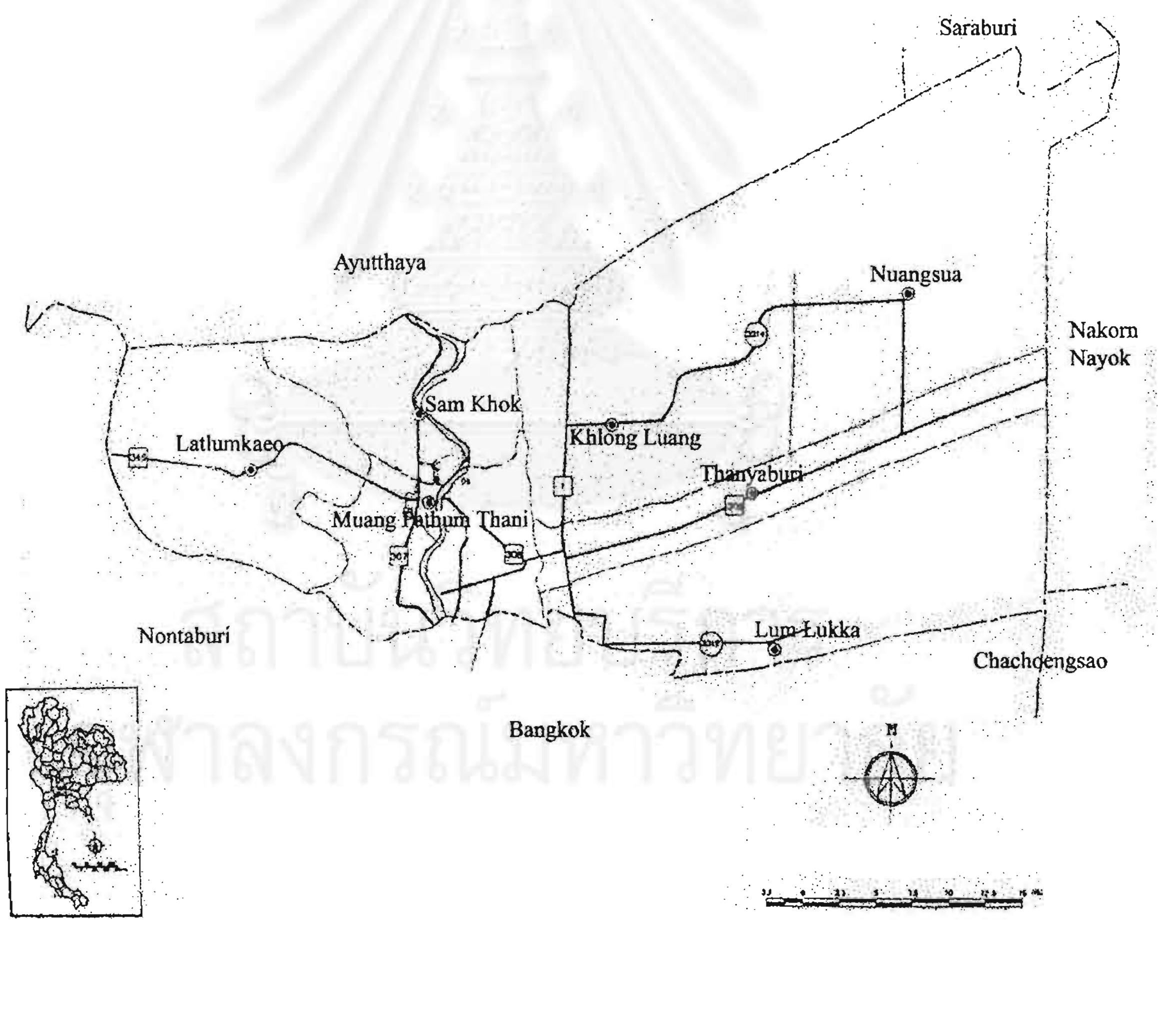


Figure 1-1 Pathum Thani province.

Due to the rapid social and economic development in recent years, many activities are increasing. The trend of environmental problems are more serious. So that the Pathum Thani has been chosen to be the pollution control area in year 1995. One of the serious problems is solid wastes disposal and management. However ,there is no definite and practical operating plan for solid waste management. It is therefore necessary to look for and prepare disposal areas, as the first step for solid waste management.

One of the strategy in solid waste management is to bring the database management system (DBMS) in decision making as related to natural resources and environmental management for the most effectiveness. Nowadays, it is accepted that the GIS can be applied to planning and management of natural resources and environment. Therefore, collecting, managing and manipulating these data into a suitable format is becoming increasingly challenging. Many environmental models require spatial data that most easily stored and managed using a Geographic Information System (GIS).

1.2 Objectives

1.2.1 To assess the relations between populations growth, resettlement and generation rate of solid wastes in Pathum Thani area.

1.2.2 To review the physical characteristics and land use of Pathum Thani area.

1.2.3 To analyze and determine the potential and suitable area for sanitary landfill.

1.3 Scope of Work and Anticipated Results

This study aims at selecting of potential areas for the sanitary landfill in Pathum Thani province. Overlay technique and weight rating system are employed in identifying the potential areas. The criteria based on the theory of solid waste disposal and fundamental principles of sanitation are established. The study area covers on Pathum Thani province. Solid wastes defined under this study is only domestic wastes which will be generated in the next 10 years from now. Parameters employed in the site selection for solid wastes dispose and management are as follow:

1.3.1 Number of population, number of house, and number of resettlement including life style of the people which related to solid waste generation and area required to be the solid waste disposal site.

1.3.2 Physical characteristics of the area: the topography, soil characteristics, geology, water resources, hydrometeorology, administration, and transportation.

1.3.3 Land use and urban plan of the Pathum Thani province.

It is anticipated that towards the end of this study the trend of population growth, generation rate of solid wastes, and quantity as well as quality of solid wastes will be achieved in the next 10 years from now for the Pathum Thani area. The most potential and suitable areas for the solid waste disposal by the sanitary landfill method will be determined in the light of environmental and public health aspects. Finally, the contribution of this study should be an important part of the overall plan for solid waste management.

1.4 General Methodology and Approach

The first step under the present study is the characterization and analysis of the solid waste in terms of quantity and quality within the study area.

The present conditions as well as the next 10 years scenerio of urban wastes have been assessed based on the population growth and life style.

The second step is concerned with the review of existing natural and socio-economic environment of the Pathum Thani area. Besides, the future development plan of the area has been taken into consideration.

The third step involves the development of site selection criteria for solid waste disposal by the sanitary landfill method. The overlay technique, weight rating system, as well as the GIS have been integrated for the present study.

Finally, the potential and suitable areas for solid waste disposal have been proposed for the Pathum Thani area.

The concept of general methodology and approach are summarised and presented in Figure 1-2.

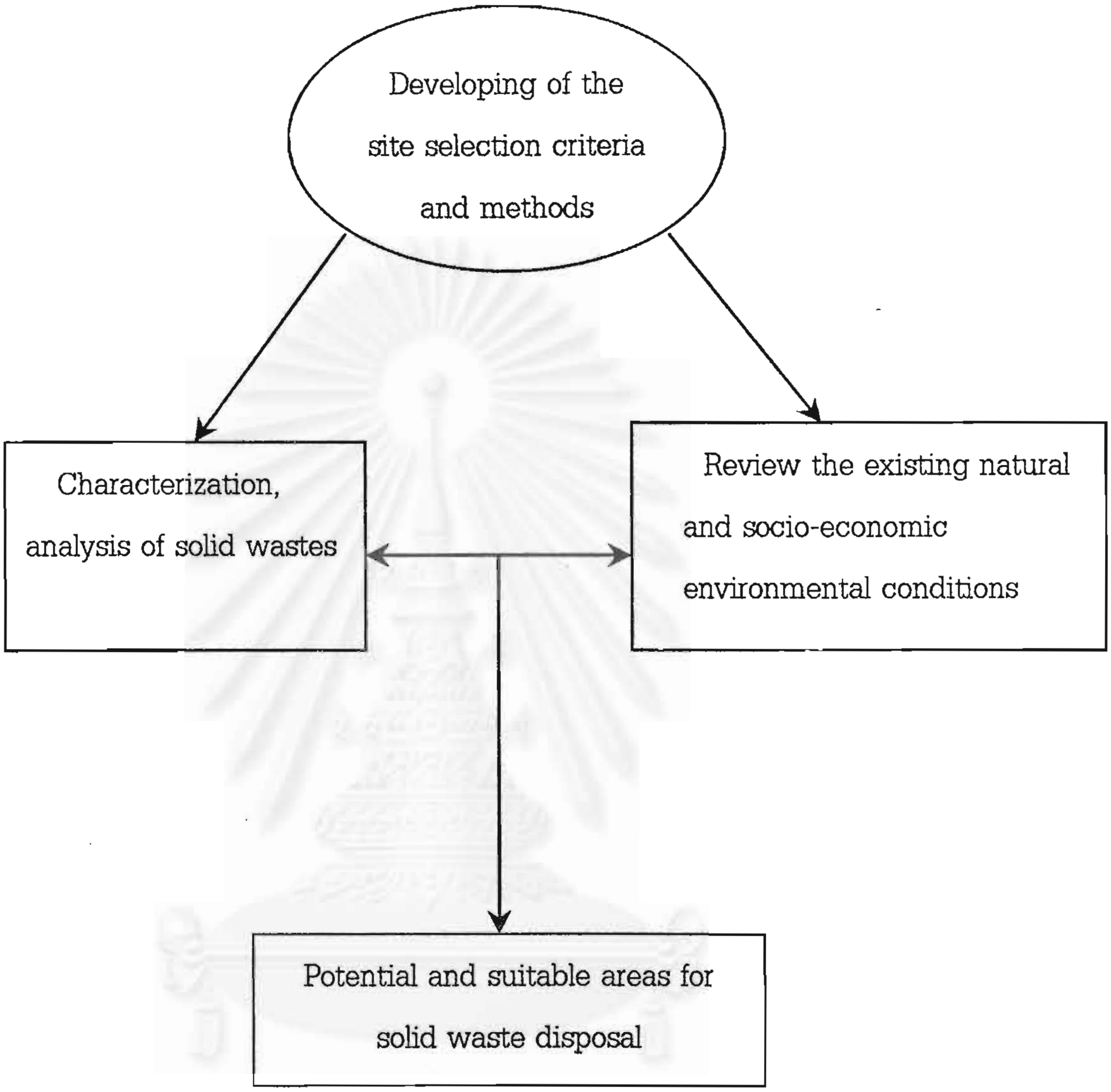


Figure 1-2 Conceptual diagram of the general methodology and approach for the site selection of solid waste disposal in study area.

1.5 Previous Works

Thamrongkeit (1987) studied comunities growth in Pathum Thani especially Prachatipat and Khlong Luang sanitary districts. The study covers population, economy, social and physical conditions. Finally, the present land use pattern has been analysed and served as the background to predict the future land use pattern of these two districts.

Wright, et al. (1989) recommended that the selection of disposal site must be completely consider. Factors used to decide are topography, surface water, groundwater, soil characteristics, geology, sensitive area, population, and transportation.

Disathein (1992) selected disposal sites in Saraburi province. She uses eight physical factors, such as, slope, type of soil, soil depth, soil permeability, geology, ground water level, surface water flow and land use as primary factors. The equation employed in the study is as follows:

$$S = W_1R_1 + W_2R_2 + ... + W_nR_n$$

Where S = score of all factor

W_1 to W_n = importance value of each factor

R_1 to R_n = capability value of each polygon. However, additional secondary factors, such as, road, railway, river and canal are also employed in her study. Finally, the GIS is used in delineating three levels of suitability of disposal sites, namely, high, medium, and low.

Ruengnon (1994) studied the implication of expanding Bangkok Metropolis on the Pathum Thani area. Besides, he attempted to illustrate the relationship between physical factors and socio-economic factor using the sieve analysis and overlay technigue. Lastly, he had discovered the total area of Pathum Thani of 1,512.91 square kilometers can be further subdivided into the residential area of 227.62 square kilometers and the industrial area of 44.76 square kilometers.

Toraksa (1995) used the geographic information system in the planning of solid waste management in Pathum Thani province. The spatial data, such as, administration, transportation, surface water, including the sites of solid waste generation are compiled in the topography base map of scale 1:50,000. The non-spatial data, such as, population, number of houses, quantity of solid wastes, existing solid waste management and disposal sites. She attempted to quantify the non-toxic and toxic wastes generated from five different sources, namely, housing, industry, hospital, market, and commercial area.

Mineral Resources, Department (1995) conducted the preliminary study on potential sites for solid waste disposal in Ubonrachathani province. The geology and subsurface water quality are used to choose the site along with these criteria: (1) the area free from frequent flood, (2) the area without ground water well, (3) the area without economic mineral deposit, (4) the area underlain with impervious soil layer, (5) the area with deep water-table and less groundwater yield., and (6) the area underlain by bed rock with high strength. In addition to these six positive factors earlier outlined, an attempt has been made to take other negative factors into consideration, namely, river line, flood-prone area, national park, road, and historical sites. Finally, the potential sites are classified as most suitable, moderately suitable, and less suitable.

Jearapattranon (1996) applied the GIS for the land use planning in Saraburi municipality. Among one of the land use planning aspects is the potential sites for solid waste disposal. The factors employed in the site selection of solid wastes are, namely, soil depth, soil permeability, soil texture. Besides, the negative factors, notably, natural forest, class 1 and 2 watershed, human settlement, steep-slope area.

CHAPTER 2

CONCEPTS OF SOLID WASTE DISPOSAL

According to definitions in the Public Health Act B.E. 2484 (1941) amended by the Public Health Act (No.3) and B.E. 2497 (1954), "solid wastes" mean pieces of paper, cloth, food, commodity, ash, animal remains, including other objects collected from roads, markets and other places, as reported by the Environmental Quality Standard Division (1989)

Residential, commercial and industrial activities generate a wide variety of wastes that have different effects on water and soil qualities. Although general categories might include garbage, rubbish, construction wastes, abandoned vehicles, and other kinds of materials, it is more useful to deal with the individual component of constituents. In a general way, these can be broken down into food or organic wastes, paper products, metals, glass, plastics, cloth, brick, rock and dirt leather and rubber, yard wastes and wood, with organic wastes and paper products constituting almost 75 % of the total weight.

Some of these materials, such as brick, rock, and glass are essentially inert and pose less pollution problems. Organic matter, however, needs to be decomposed and, therefore, reguires a significant amount of oxygen. With decomposition, methane and carbon dioxide increase the hardness and acidity of water, which may lead to solution and leaching. Ashes are generally rich in potassium, nitrates, phosphates and other elements that can be leached out by percolating water. The nature of solid wastes, and the concentrations of leacheates are important in determining the potential threat to the hydrologic environment.

Hoowichit (1986) described the sources and types of solid wastes related to land use and activities (Table 2-1). In municipality, solid wastes are generated from both residential and commercial zones. They are food wastes, rubbish, ashes, special wastes, demolition and construction wastes, and hazardous wastes.

In this study, solid wastes are defined as wastes arising from human activities in residential and commercial zones, including from any type of industries that are useless or unwanted. Solid wastes are food wastes, rubbish, ashes, special wastes, demolition and construction wastes.

Table 2-1 Sources and types of solid wastes

Sources	Land use/activities	Type of solid wastes
Residential Zones*	Single-family, multifamily dwellings, apartments, condominiums, etc.	Food wastes, rubbish, ashes, special wastes
Commercial Zones*	Shops, stores; restaurants, markets, office buildings, repair shops, hospitals, etc.	Food wastes, rubbish. Ashes, demolition and construction wastes, special wastes and hazardous wastes.
Industrial Zones	Construction, mining, textile industries, etc.	Food wastes. Rubbish, ashes, demolition and hazardous wastes.
Public Areas	Streets, parks, beaches, playgrounds, recreation areas, etc.	Special wastes, rubbish
Agricultural Zones	Farms and fields	Agricultural wastes, rubbish, hazardous wastes.

Note : *Municipality covers both of residential and commercial zones.

Source: Hoowichit (1986)

2.1 Classification of Solid Wastes

According to the earlier mentioned terminology, definition of municipal solid wastes can be classified (Peavy, et al. 1988) as presented in Table 2-2.

The quantity of generated solid wastes depends upon the influence of five major factors. They are :

(a) geographic location,

(b) economic status,

(c) activities of population,

(d) living standard, and

(e) public health attitude.

Decision making and planning of solid waste management system thus requires data on these components. Under the present study, the hypothetical quantity of solid wastes is defined as average generation rate of solid waste per person multiply by the number of population in Pathum Thani province.

Table 2-2 Classification of materials comprised in municipal solid wastes.

Components	Description
Food wastes	The animal, fruit, or vegetable residues (also called garbage) resulting from the handling, preparation, cooking, eating of foods. Because food wastes are putrefiable, they decompose rapidly, especially in warm weather.
Rubbish	Combustible and noncombustible solid wastes, excluding food wastes of other putrefiable materials. Typically, combustible rubbish consist of materials such as paper, cardboards, plastics, textiles, rubber, leather, wood furniture, and garden trimmings. Noncombustible rubbish consists of items such as glass, crockery, tin cans, aluminium cans, ferrous and non-ferrous metals, dirt, and construction wastes.
Ashes and residues	Materials remaining from the burning of wood coal, coke and other combustible wastes. Residues from paper plants normally are not included in this category. Ashes and residues are normally composed of fine, power materials, cinders, clinkers, and small amounts of burned and partially burned materials.
Demolition and Construction wastes	Wastes from razed buildings and other structures construction wastes are classified as demolition wastes. Wastes from the construction, remodeling, and similar structures are classified as construction wastes. These wastes may include dirt, stones, concrete, bricks, plaster, lumber, shingles, and plumbing, heating and electrical parts.
Special wastes	Wastes such as street sweeping, roadside litter, catch-basin debris, dead animals and abandoned vehicles are classified as special wastes.
Treatment-plant wastes	The solid and semi-solid wastes from water, wastewater, and industrial wastes treatment facilities are included in this classification.

Source: Disathien (1992)

2.2 Treatment and Disposal of Solid Wastes

2.2.1 Composting

Pavoni, et al. (1975) defined that composting is biochemical degradation of organic factor of the solid waste material. Its end product is humus like substance that is used primarily for soil conditioning.

Lohani (1984) stated that composting is the oldest method of organic waste disposal and defined as decomposition of heterogeneous organic matters by microorganisms in moist warm, aerobic environment, resulting in degradation and reduction of organic matter into a sanitary nuisance-free humus like material, which can be use as fertilizer, soil conditioner, bulking agent for reclamation cover material for the landfill.

He pointed out this process is suitable for the developing countries due to following reasons,

(a) It is a simple method.
(b) Small amount of residue is left for the landfill.
(c) It is easily adaptable to local conditions.
(d) Composting has low toxic substance.
(e) It meets the requirement of the hygienic conditions.

He also pointed out the conditions requires for the successful operation of composting as fallow:

(a) Obtaining sufficient support from the government authorities specially those related to agriculture.
(b) Suitability of the characteristics of solid wastes for composting.
(c) Price of the product should be reasonable.
(d) Composted production source should be near to competitive the market.

2.2.2 Incineration

Rimberg (1975) stated that incineration is the controlled process of burning of solid waste in furnace, boiler, or specially designed container for this purpose. The end products being ashes and the gases. Theodore and Reynolds. (1987) described that incineration involves the oxidative conversion of the combustible material to gases to be released to the atmosphere. The harmful gases must be removed before releasing to the air.

Willing (1979) stated that incineration is the waste treatment process with great particulate and gaseous emissions. Therefore, dust extractor and flue gas scrubbers are required which involve a large amount of capital expenditure and higher operation and maintenance cost. Bernt (1991) stated that the capital cost for the control of air pollution is about 10 to 20 % of the total investment cost.

Different methods of treatment, processing and disposal are applied to the countries of Asia and Pacific region. The most widely used method is landfill or open dumping. In larger cities, the availability of land for waste disposal is the major problem. In Japan and Singapore, about 65 % of the wastes is incinerated with energy recovery. Waste characteristics of these countries have relatively high calorific value due to presence of high percentage of paper, plastic, and other combustibles and low moisture content. Low-income countries of Asia Pacific region are given in Table 2-3.

Table 2-3 Disposal methods for municipal wastes in selected countries in ESCAP region.

Country	Disposal Methods			
	Land Disposal (%)	Incineration (%)	Composting (%)	Others (%)
Australia	96	1	-	3
Bangladesh	95	-	-	5
Brunei Darussalam	90	-	-	10
Hong Kong	65	30	-	5
India	70	-	20	10
Indonesia	80	5	10	5
Japan	22	74	0.1	3.9
Korea	90	-	-	10
Malaysia	70	5	10	15
Philippines	85	-	10	5
Singapore	35	65	-	-
Sri Lanka	90	-	-	10
Thailand	80	5	10	5

Source : Asian Development Bank (1995)

2.2.3 Sanitary Landfill

2.2.3.1 Definition of Sanitary Landfill

The sanitary landfill as defined by American Society of Civil Engineers (1959), is a method of disposing of refuse on land, without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area to reduce it to the smallest practical area and to cover it with a layer of earth at the conclusion of each day's operation or at more frequent intervals as may be necessary.

Sanitary landfill is a method that bringing solid wastes heap on the prepared ground and then the spread out and compact the waste with soil for preventing odors, insects, leachate and other nuisances. Organic matter in the waste will be decomposing by nature process. This reduces the volume of solid waste, generates the methane gas and leachate in layer of waste. So landfill operation should have strategy to prevent and correct waste water or leachate, and to ventilate methane gas from the disposal site.

This method is usually the cheapest method of waste disposal and most practical in operation. However the operation cost in the beginning stage is quite high, because of the high equipment cost and high price of land.

Table 2-4 Comparison three different kinds of waste disposal.

Item	Incineration	Composting	Sanitary Landfill
1.Operation & maintenance	-almost high technology -need skillful staff	-medium technology -need semi-skillful staff	-low technology -need normal skillful staff
2.Effective disposing	-80-90% volume reduction -eradicate infection 100%	-30-35% volume reduction -eradicate infection 70%	-0% volume reduction -eradicate a little of infection
3.System flexibility	-low	-low	-high
4.Environmental effects on			
-surface water	-none	-possible	-most possible
-ground water	-none	-possible	-most possible
-air	-some	-none	-none
-odors, insects and carrier of disease germs	-none	-may be have	-have
5.Characteristics of wastes	-Combustible, heat value not less than 800 kcal./kg. and moisture less than 40%	-able to be compost organics, moisture 50-60%	-every kind of waste except infection and hazardous wastes.

Table 2-4 Comparison three different kinds of waste disposal.(cont.)

Item	Incineration	Composting	Sanitary Landfill
6.Land size	-small	-moderate	-large
7.Capital cost	-very high	-rather high	-rather low
8.Cost for operation & maintenance	-high	-rather high	-low
9.By products	-heat energy	-soil treatment substance and separated metal	-final area can be used as park, etc. -methane gas for fuel

Source : Pathum Thani Provincial Office (1999)

The operation plan must be prepared to effectively use available land areas. Various operational methods have been developed primarily on the basis of field experience. Operations of sanitary landfill are summarized as follows.

(a) Conventional methods

Area method is used when the terrain is unsuitable for excavation of trench or low area to place the solid wastes. (Figure 2-1)

Trench method is areas where adequate depth of cover soil is available.(Figure 2-2)

Sanitary landfill practice may be carried out in every place, however some cases require the construction of embankment before operation.

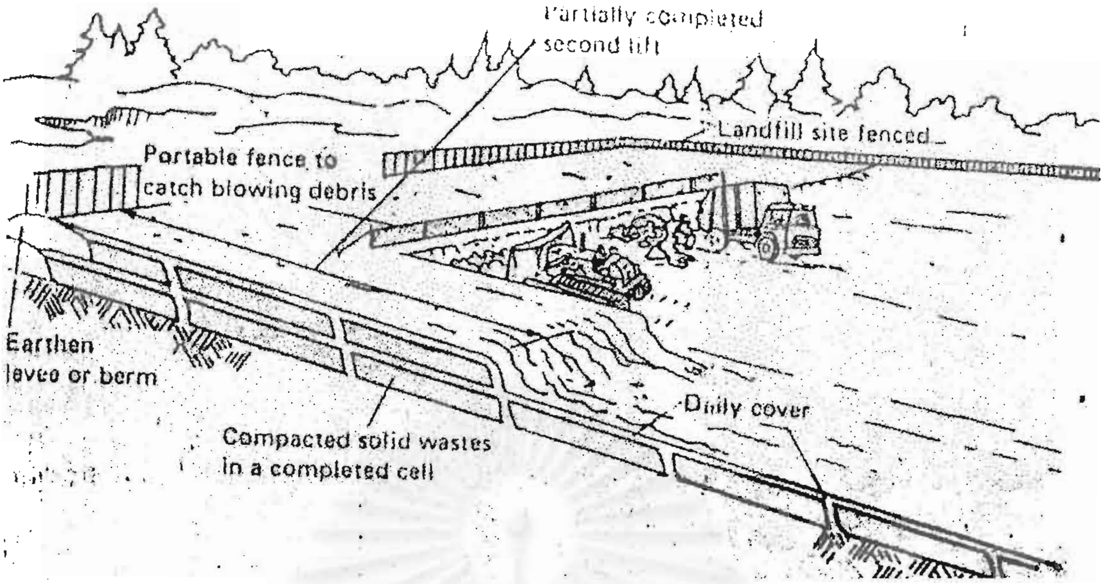


Figure 2-1 Area method (Disathien, 1992)

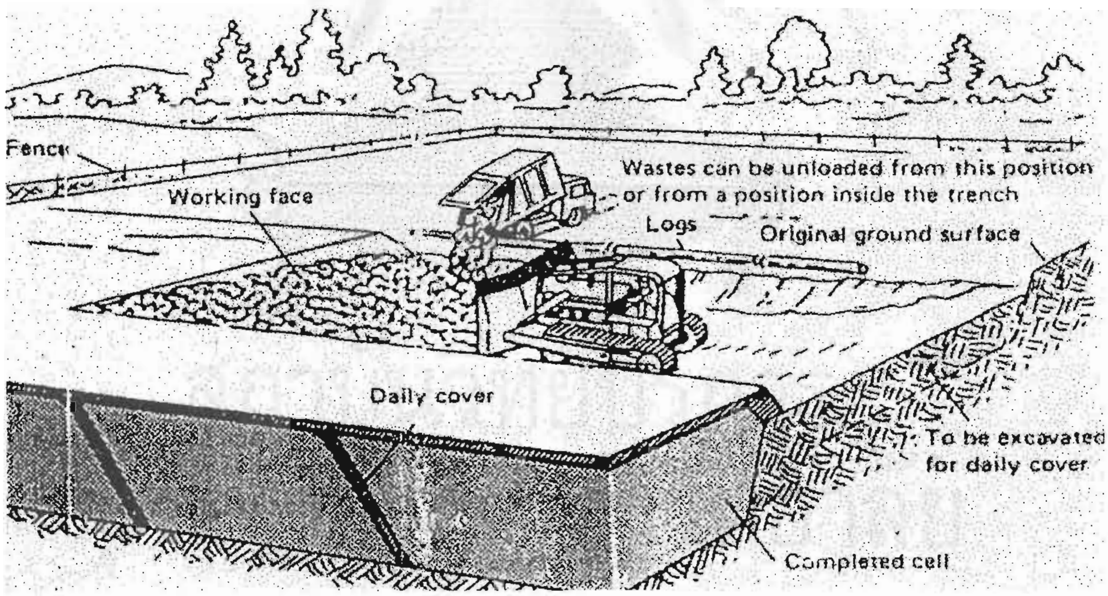


Figure 2-2 Trench method (Disathien, 1992)

(b) Depth and thickness of landfill

Generally, the bottom of landfill site must be at least 5 feet or 1 meter above the groundwater table. The standard thickness of the top of the strip which is called "Daily cover" should be 15 centimeters, intermediate cover should be 30 centimeters, and the final layer of cover soil should be at least 60 centimeters thick and soil conditions of the final overlay should be clay soil, prevent breeding flies, rats, cockroaches and reduce precipitation permeation or infiltration. The side slope of the landfill site being filled should be 45 degree for manual operation and 30 degree or less for machine operation, to allow well drainage and prevent soil erosion.

Table 2-5 Standard thickness of soil cover

Type of Soil Cover	Thickness of Soil Cover (cm.)
Daily cover	15
Intermediate cover	30
Final cover	60

Source : Office of the National Environmental Board, (1987)

2.2.3.2 Environmental Impact of Sanitary Landfill

Decomposing is a natural process after filling and covering solid wastes in each landfill site. The aerobic and anaerobic decomposition of solid wastes occur. In the first year, temperature and the amount of generated gas are normally very high. Later, decomposing rate reduces as a result of rather constant temperature. If the total solid wastes consist of 15% garbage, the decomposition occurs slowly but the decomposition of rubbish occurs quickly. In general, decomposing should completely finishes in 12 months.

For the gas generation, the principle gases produced from the anaerobic decomposition of organic components are methane and carbondioxide. Peavy, Rowe and Tchobanoglous (1988) described the first step of decomposition in which carbondioxide reaches a peak and then is slowly tapped off. While the volume of methane is increasing, its density is more than carbondioxide and thus it moves toward the bottom of the landfill site. Carbondioxide will also move downward through the underlying formation until it reaches the groundwater and is rapidly soluble water.

The gas-movement in landfill can be controlled, by designing and constructing vents and barrier of materials that are more impermeable than the soil. Nevertheless, the use of compacted clays is most common. The thickness varies, depending on the types of clay and the degree of control required. Generally, the thickness of clay is from 0.15-1.25 meter.

For the leachate generation; water may enter the landfill site from external sources, such as, surface drainage, rainfall, and groundwater. The leachate causes deterioration of groundwater and surface water quality. The occurrence of leachate-movement occurs depends on the characteristics of the waste materials. The leachate discharge rate per unit area is equal to the value of the coefficient of permeability expressed in meters per day.

The control of the movement of leachate is equally important to the elimination of surface water infiltration. Ultimately, it may be necessary to collect and treat the leachate to percolate to the groundwater. The best practice is to cell for its elimination containment. The use of clay has been a favored method of reducing or eliminating the percolation of leachate. With the use of an impermeable clay layer, appropriate surface slope (1-2%) and adequate drainage surface, infiltration can be controlled effectively.

The settlement of landfill site depends on characteristics of wastes and compaction density which affect the consolidation, the leachate and gases formed in the landfill site. Particularly, the height of completed fill influences the compaction ratio and the degree of consolidation.

The selection of proper landfill site is important. It is possible to select sites which are not suitable for agriculture, and other development activities, or abandoned mining.

All of above there are 3 kind of waste disposal method, namely, incineration, composting, and sanitary landfill, the incineration have more than 10% ash. These ash must be disposed by landfill. In addition, the composting is the process that use more time, generate many residual wastes which must take for landfilling. So the sanitary landfill should be a final disposal of both the incineration and the composting.

The case study of Bangkok Metropolis by the TAMS-PIRNIE international Co. on various disposal system (1987-1988) revealed that only 70% of the total solid wastes can be incinerated. However, out of 70% incineratable wastes produces 7% of ash. In addition, only 65% of total solid waste can be composted with 35% left as residue. It is note that the demand of composting fertilizer in Bangkok area is only 50% of the supply. Therefore, the remaining solid waste after composting will be 67.5% of the total solid wastes.

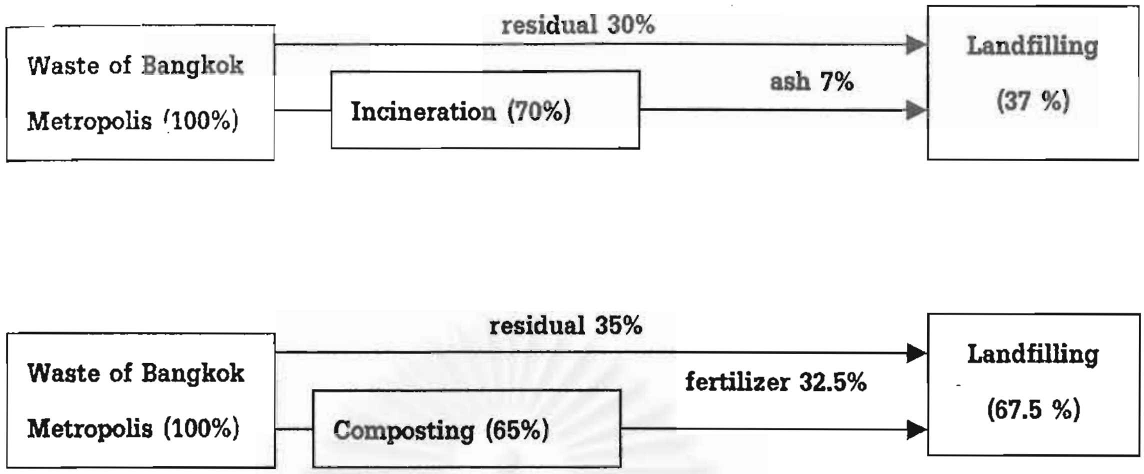


Figure 2-3 Results of comparison on Bangkok metropolis disposal method.

Sanitary landfill is based on the results of preliminary technique and engineering design, it is proved to be better than other disposal methods. The initial investment is also low compared with other disposal methods.

Table 2-6 Comparison between various disposal methods

	Incineration	Composting	Landfill
-Total quantity of disposable wastes (%)	63	32.5	100
-Left out wastes (%)	37	67.5	-
-Ratio of operation cost vs. landfill method	4.6	2.3	1.0

Source: Thongphawat (1990)

Comparison of waste disposal operation cost in Bangkok shows that the ratio of the present value of operation cost per ton of incineration: composting: sanitary landfill is 4.6:2.3:1.0

Table 2-7 Comparison of operation cost of 3 different disposal methods.

Type of cost	Cost (Baht/ton)		
	Incineration	Composting	Landfill
Operation	442	194	136
Organisation and management	325	187	29
Total	**767**	**381**	**165**

Source : JICA (1987)

The sanitary landfill, also known as a cut-and-cover process, is a relatively new method and is at present one of the most acceptable ways of disposing of solid wastes. However, only about 40 % of the nation's solid wastes have been disposed using this method (Table 2-8). These operations may take place in the depression, such as canyons, ravines, or old quarries, or may even be carried out on a flat area or often along bays and estuaries. Waste material is dumped, compacted each day into layers or cells, and then cover with a layer of soil. The ratio of compacted refuse to soil is usually about 4:1. The soil cover serve to eliminate odors, unsightly appearance, and also the pest problems that plaque open dump sites. In addition, the refuse is protected by the soil covering from direct precipitation, and consequently surface runoff of polluting substances or liquids is decreased. Sanitary landfills, despite their daily soil coverings, may still be unsanitary and produce water contamination problems if located in hydrologically unsuitable areas. The type of management and operation of individual landfill sites may produce condition ranging from nearly open dumps of the one hand to very clean operation on the other.

Table 2-8 Waste disposal in each area in Thailand 1994

	Quantity of pick up waste (ton/day)	Landfill (ton/day)	Composting (ton/day)	Incineration (ton/day)	Open Dump (ton/day)
1.Bangkok	6,500	5,000	1,100	-	400
2.Municipality (included Pattaya)	4,500	600	-	-	3,900
3.Public Health	600	-	-	-	600
4.Other area	2,400	-	-	-	2,400
Total	14,000	5,600	1,100	-	7,300

Source: 1.Waste disposal factory division, Department of care clean, Bangkok

2.Pollution Control Department

2.2.3.3 Criteria for the Site Selection of the Sanitary Landfill

The sanitary landfill needs controlling and preventing environmental impacts in the long term. The following criteria are important for design, consideration and operation of landfills.

Land requirement

It is important to ensure that sufficient land area is available. It is desirable to have sufficient area to operate for at least 5-10 years at each site, depending on the generated amount of solid wastes, characteristics of solid wastes, compaction ratio, depth of landfill and number of lifts. At each site, 20- 40 % of surplus area should be provided for other operation, e.g. roads, office-building, equipment, shelters, etc. (Disathien, 1992)

Topographic condition

This can be compared with the mean sea level, and geomorphology; plain, hillslope, footslope, swamp, or floodplain area. These factors should be considered in selection of useable landfill site, and decision for area development and operation cost. For example, if a site is hillslope or footslope, it should not be over 6 %. The suitable slope is about 1-2% for good drainage systems. (Disathien, 1992)

Bed rock

If the area is underlain with a great bed rock, it is considered most suitable to support the weight of solid wastes. (Pollution Control Department, 1999)

Soil characteristics and soil suitability

An important factor concerning soil is the liquid waste percolation or soil permeability. The leachate may contaminate the groundwater and causes serious health hazard. The leachate discharge rate depends on the value of the coefficient of soil permeability. For the landfill site where soils are clay and/or silty clay and permeability is 10^{-6}-10^{-8} cm./sec., is regarded as impermeable, and that there will be no need for creating an impervious structure at the bottom of the landfill on site preparation. La Grega, Buckingham and Evans (1994) assigned criteria for choosing disposal site that should be clay with soil permeability less than $1x10^{-7}$ cm/sec.

For the soil cover, utilization of on-site earth materials should be maximized. Figure 2-4 identifies the suitability of the soil cover for sanitary landfill to control surface infiltration, discharge of the leachate through seepage to the groundwater system.

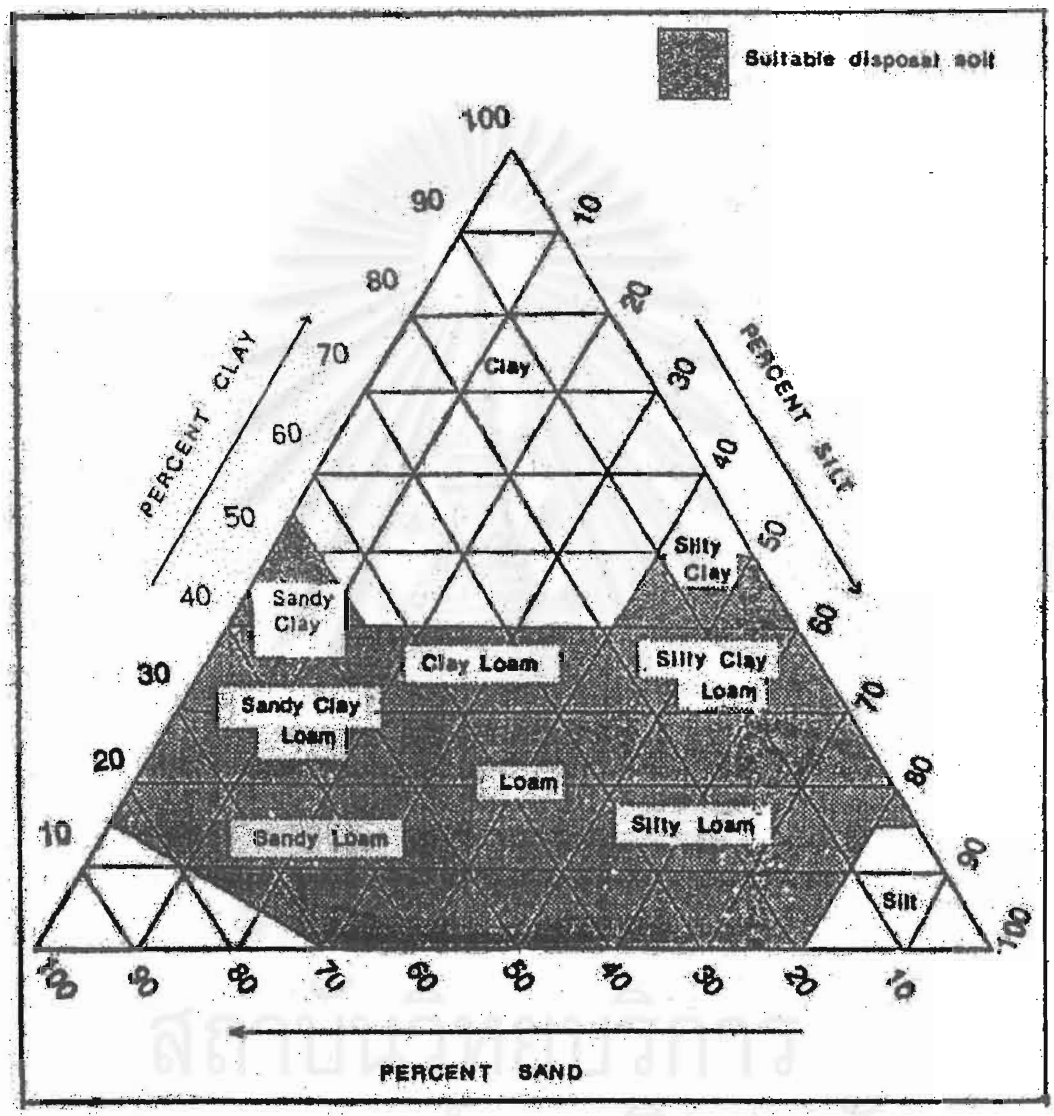


Figure 2-4 Suitability of soil cover for sanitary landfill. (Disathien, 1992)

Only eight soil types are suitable as follows: (1)sandy clay, (2)sandy clay loam, (3) silty loam, (4)sandy loam, (5)clay loam, (6)loam, (7)silty clay, and (8)silty clay loam following the soil texture standard of the International Society of Soil Science.

Haul distance and transportation

Distance is one of the most important factors to be thought of in disposal site selection. The distance from municipality should be less than 15 kilometers which requires the least cost (Environmental Quality Standard Division, 1989). A landfill site should have accessibility to roads or temporary roads to unloading areas and there should be no traffic problem. The transportation of wastes should not pass through any central business or residential area.

Location

The site should be located above 5 kilometers from community to avoid the nuisance of odor, vapor and dust to man's health. The location should be farther than 300 meters from the main road (Environmental Quality Standard Division, 1989). and should be far from airport area of not less than 5 kilometers.

Hydrology

The site must not locate within the watershed area class I and class II (Cabinet resolution on the May 28,1985). It should locate far from natural water resources including wetland or man-made water body of at least 300 meters, excluding the water body used in the landfill site. (Pollution Control Department, 1999)

Groundwater

The water table at landfill site should be low or deep enough. Distance between the lowest lift of landfill sites and water table is at least 1 meter. Besides, the present technology of so-called "Betomat", "Geomenbrane" and "Geotextile" can be applied at the bottom layer for protecting leachate contamination to the groundwater.

Groundwater well and water supply station

The distance from existing nearest wells and water supply stations to the site should more than 700 meters. (Pollution Control Department, 1999)

Historical and archeological sites

The site should be located far from ancient remains boundary further more 1 kilometers following "The ancient remains, ruins, art objects and the National Museum in Bangkok Act". (Pollution Control Department, 1999)

River and airport

The disposal site should be far from river of 200 feet or 60 meters and far from air-port of 500 feet or 150 meters (Sukthawon, 1998 referred to Levin, 1996)

2.3 Geographic Information System (GIS)

2.3.1 Definition of GIS

Burrough (1986) defined GIS as "A powerful set of tools for collection, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purpose".

Aronoff (1989) defined GIS as "Any manual or computer based set of procedure used to store and manipulate geographically referenced data".

Nappi (1991) said the "GIS" is a computer hardware and software system designed to permit an end user to input, store, manipulate and display geographically reference data.

So GIS are computer-based tools to capture, manipulate, process, and display spatial or geo-referenced data. They contain both spatial data (coordinates and topological information) and attribute data, that is, information describing the properties of geometrical objects such as points, lines, and areas.

2.3.2 Component of GIS

Computer Hardware

The computer hardware includes Central Processing Unit (CPU), Disk Drive Storage Unit, Digitizer, Plotter, Tape Drive, and Visual Display Unit.

Computer Software

There are several software packages of GIS, Arc/Info is the one popular for site selection (Vieux,1991). An important characteristics of GIS is that it is an integrating technology. GIS makes it possible to combine information themes of many fields, and undoubtedly has accelerated this trend.

Data

A GIS data base can be divide into 2 basic types of data: graphic and non-graphic. Each of these types has specific characteristics, and each has different requirements for efficient data storage, processing, and display.

Graphic data were digital descriptions of map features. They included-the coordinate, rules, and symbols that define specific cartographic elements on a map

Graphic data represent map images in computer-usable form Graphic data use six types of graphic elements to depict map features and annotation. Three major of graphic elements are as follow:

point : A single x,y coordinate pair that defines the location of a map feature whose boundary or shape is too small to be displayed as an area or line, such as locations of cities on a small scale map, wells, meteorological stations, schools and mountain peaks.

line : A set of ordered points which are connected and represent a map feature that is too narrow to be displayed as an area, or a map feature that has no width. Examples of line feature are roads, streams, contour lines and faults.

polygon : An area feature, a closed figure bounded by line features that enclose a homogeneous area, defined by the set of arcs which comprise its border, and a label point within the polygon which is used to assign a User-ID.(Figure 2-5) (ESRI, 1992)

Non-graphic data are representations of the characteristics, qualities, or relationships of map feature and geographic locations. They are store in conventional alphanumeric formats, though document management systems that manage data as graphic images in raster format are beginning to be linked with GIS technology.

Non graphic data may be further divided into attributes, geographically referenced data, geographic indexes, and spatial relationship. So they are often called textual data or attributes.

The spatial data (graphic data) display picture or coordinate of point, line or area that are components of map whereas the attribute data (nongraphic data) will show details related to that point, line, or area feature.(Antenucci, 1991)

The graphic data in GIS are: (1) vector structure (2) raster structure. Data in vector system use "point" and "line" to display geographic characteristics. Many points link each other continuously one by one become a line called "arc" as river or road. If arcs links arcs become boundary or area called "polygon" by using x,y coordinate to indicate position and characteristics of things and then process for figure, characters, and details output. Example of the software is Arc/Info. Another one, raster structure included "grid cell" or "pixel" a square or a rectangle figure. The area of grid depends on resolution of data. Each grid cell carries number which represent data that will bring to construct map. Row and column are index positions and directions. "Point" will replace with relation and distribution quantity to near grid cell. This structure is easy to use computer to organizing, process and display output. Example of software are ILWIS, SPAN, IDRISI etc.

The GIS maintains the relationship between graphic and nongraphic data. It use identifiers to link graphic elements and their respective nongraphic attributes. (Figure 2-6)

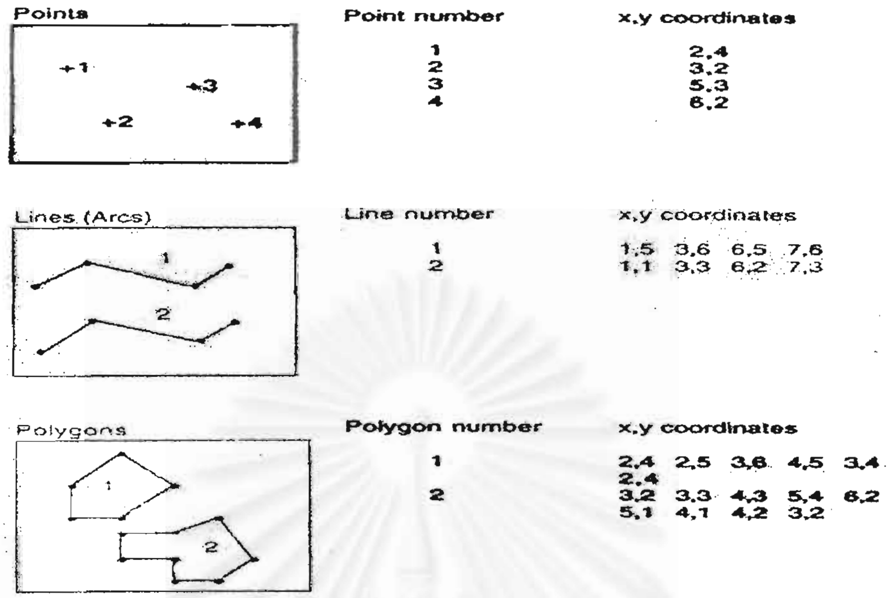


Figure 2-5 Point, line and area feature.

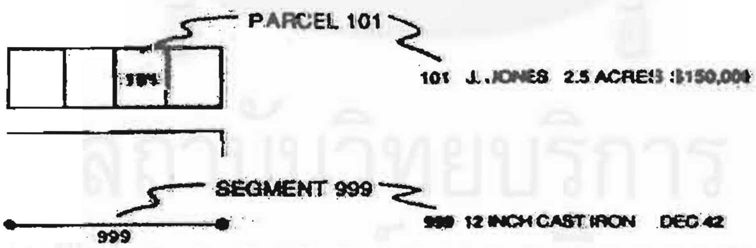


Figure 2-6 Graphic-nongraphic relationship.

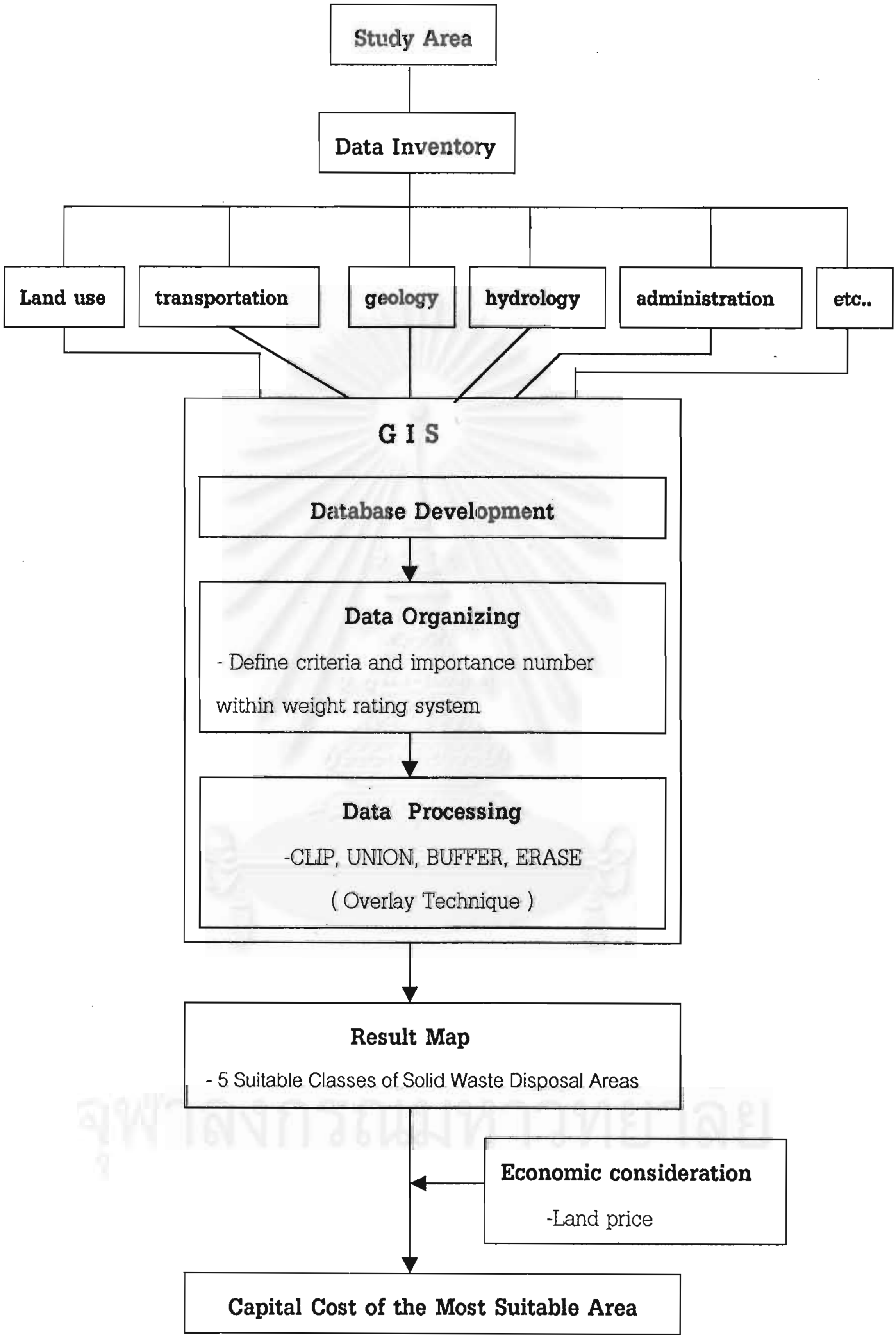


Figure 2-7 The GIS analysis procedure

CHAPTER 3

ENVIRONMENTAL SETTING OF PATHUM THANI

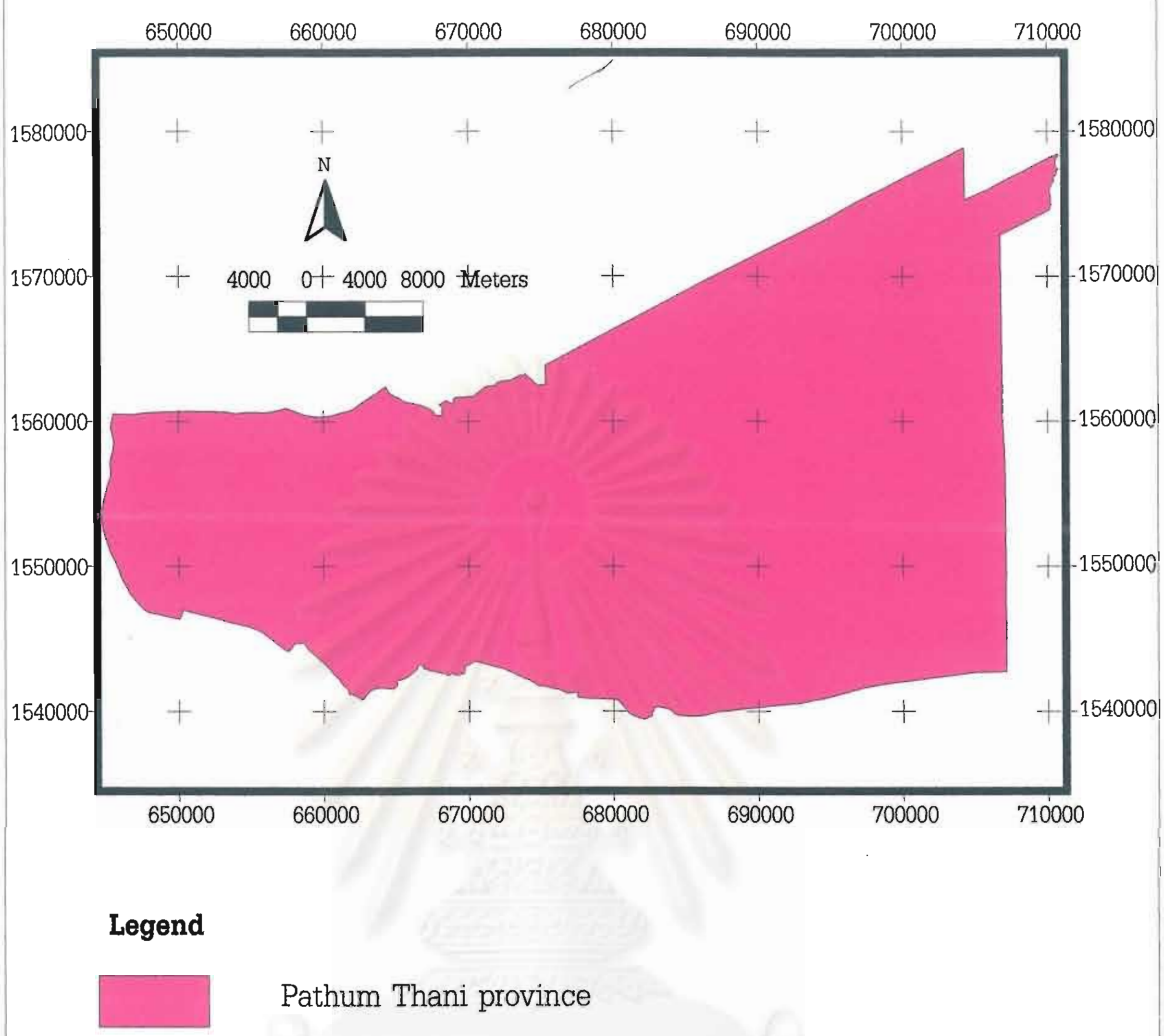
3.1 Location and Size

Pathum Thani is a province situated in the lower central plain of Thailand. Pathum Thani lies between latitudes $13^{\circ}\ 55'$ north to $14^{\circ}\ 18'$ north and longitudes $100^{\circ}\ 20'$ east to $100^{\circ}\ 57'$ east. The Pathum Thani is adjacent to Bangkok in the north covering an area of about 1,520 square kilometers. It is bounded in the north by Phra Nakhon Si Ayutthaya and Saraburi provinces, in the east by Nakhon Nayok and Chachoengsao provinces, in the west by Phra Nakhon Si Ayutthaya and Nonthaburi provinces, on the south by Nonthaburi province and Bangkok. The Pathum Thani is located in the floodplain area on both sides of Chao Phraya river.

3.2 Topography

The topography of the Pathum Thani is almost entirely dominated by flat plain with an average elevation of 2.30 meters above the mean sea level, and an average slope of under 2%. The Chao Phraya river flows through the middle part of the province. The west bank includes Amphoe Lat Lum Kaeo, part of Amphoe Muang and part of Amphoe Sam Khok. Whereas the east bank includes Amphoe Khlong Luang, Amphoe Nongsua, Amphoe Lumlukka, Amphoe Thanyaburi,part of Amphoe Muang and part of Sam Khok.

In rainy season (especially in September), the level in Chao Phraya river always rises up approximately 50 cm. above the average water level. Because of this, there are floodings on both banks but the east bank has less problem than that of the west bank because it has many canals to assist the flood drainage.



Source: Royal Thai Survey Department (1982)

SELECTION OF POTENTIAL SOLID WASTE DISPOSAL AREAS

IN PATHUM THANI PROVINCE

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Inter-Department of Environmental Science

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Figure 3-1: The location map of the study area, Pathum Thani province.

3.3 Climate

The climate of lower central Thailand region is governed by monsoons and characterized by three distinct seasons. The rainy season from mid-May to October when the region is under the influence of the southwest monsoon with the average monthly rainfall above 150 mm., relative humidity greater than 70%. In September the humidity reaches maximum of 80% with the average monthly rainfall of 283.4 mm. From November to the end of February, northeast monsoon brings dry cool air from continental Asia. The average temperature is about 27°C., and the average monthly rainfall is below 20 mm., the relative humidity below 70%. The hot dry summer extends from the end of February until mid-May when the region is under the influence of the southeast monsoon. The average temperature is about 30°C. and usually reaches maximum in May.

The Don Muang meteorological station, the nearest station to Pathum Thani, reveals the climatic condition of this province as summarized in Table 3-1.

Table 3-1 The climate of Pathum Thani province as average from 30-years period (1969-1998)

	Rainfall (mm.)	Rainy day	Temp (mean) (^{o}c)	Relative Humidity (%)
January	9.6	1.2	26.3	67
February	10.7	1.2	27.6	70
March	26.9	2.3	28.9	71
April	56.3	5.2	29.9	72
May	154.0	13.1	29.5	74
June	135.4	13.6	28.9	74
July	158.0	15.4	28.6	75
August	171.0	17.2	28.4	76
September	275.4	19.2	28.0	79
October	176.6	13.9	27.9	77
November	37.0	4.9	27.2	71
December	12.6	1.2	25.8	66
Annual	***1223.5***	***108.4***	***28.1***	***73***

Source : Meteorological department

Remarks: data from Don Muang station

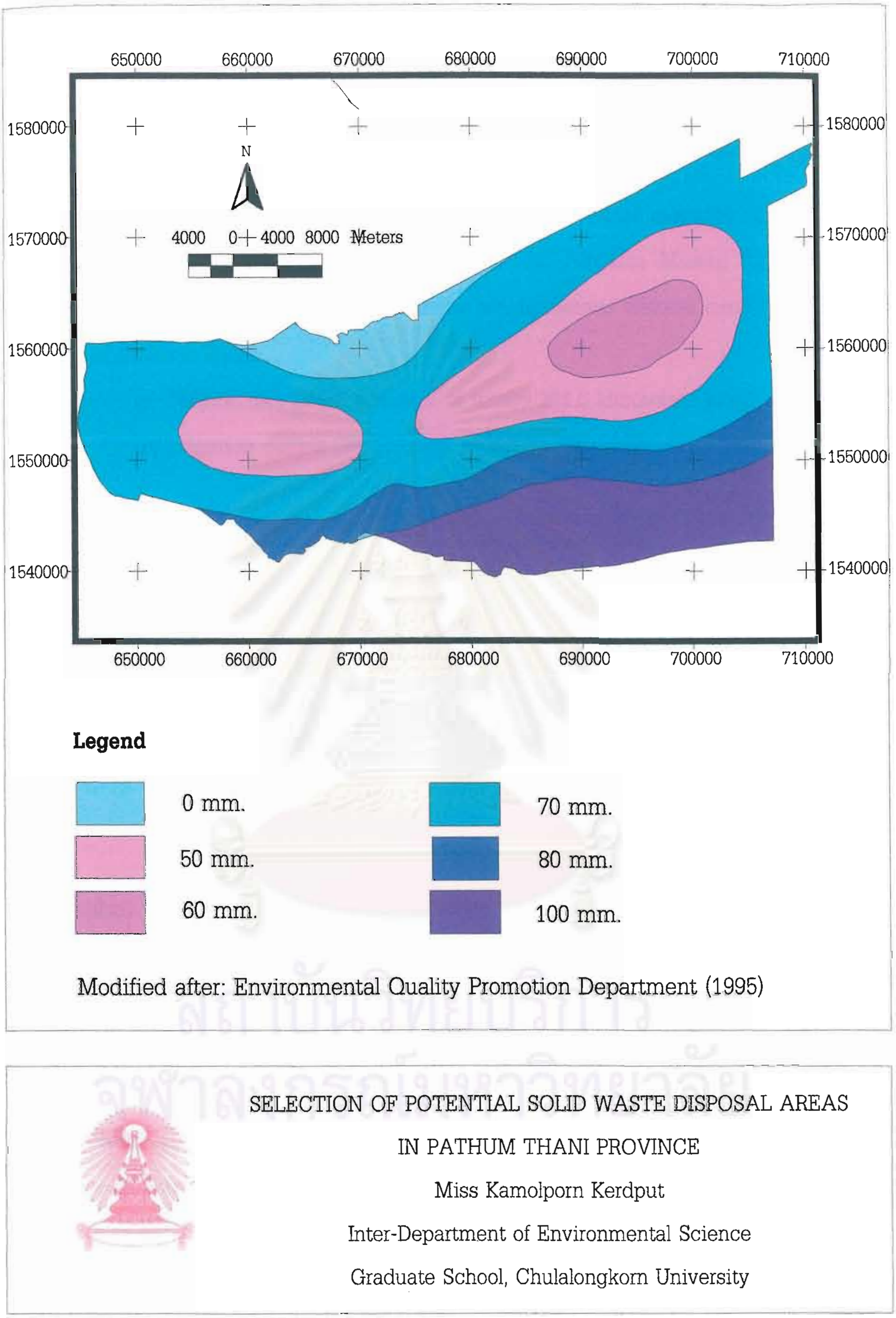


Figure 3-2 The isohyetal map of Pathum Thani province.

3.4 Water Resources

3.4.1 Surface Water

The Chao Phraya river is the important surface water resource of Pathum Thani province. It flows through Amphoe Sam Khok and Amphoe Muang for a distance of approximately 30 kilometers. Besides, there are numerous natural canals and irrigation canals in Pathum Thani..

(a) Natural canals (55 Khlongs. of totally 281.6 kilometers long)

(b) Irrigation canals (29 Khlongs. of totally 780.8 kilometers long)

These canals flow through the area in this province under different administrative Amphoes as follows :

1) Amphoe Muang-: Chao Phraya river, Khlong Bang Pho Tai, Khlong Bang Luang, Khlong Bang Prok, Khlong Chiang Rak, Khlong Chao Muang

2) Amphoe Sam Khok-: Chao Phraya river, Khlong Bang Pho Nua, Khlong Bang Toei, Khlong Kwai, Khlong Sra, Khlong Chiang Rak Noi, Khlong Prempracahakom, Khlong Chaing Rak

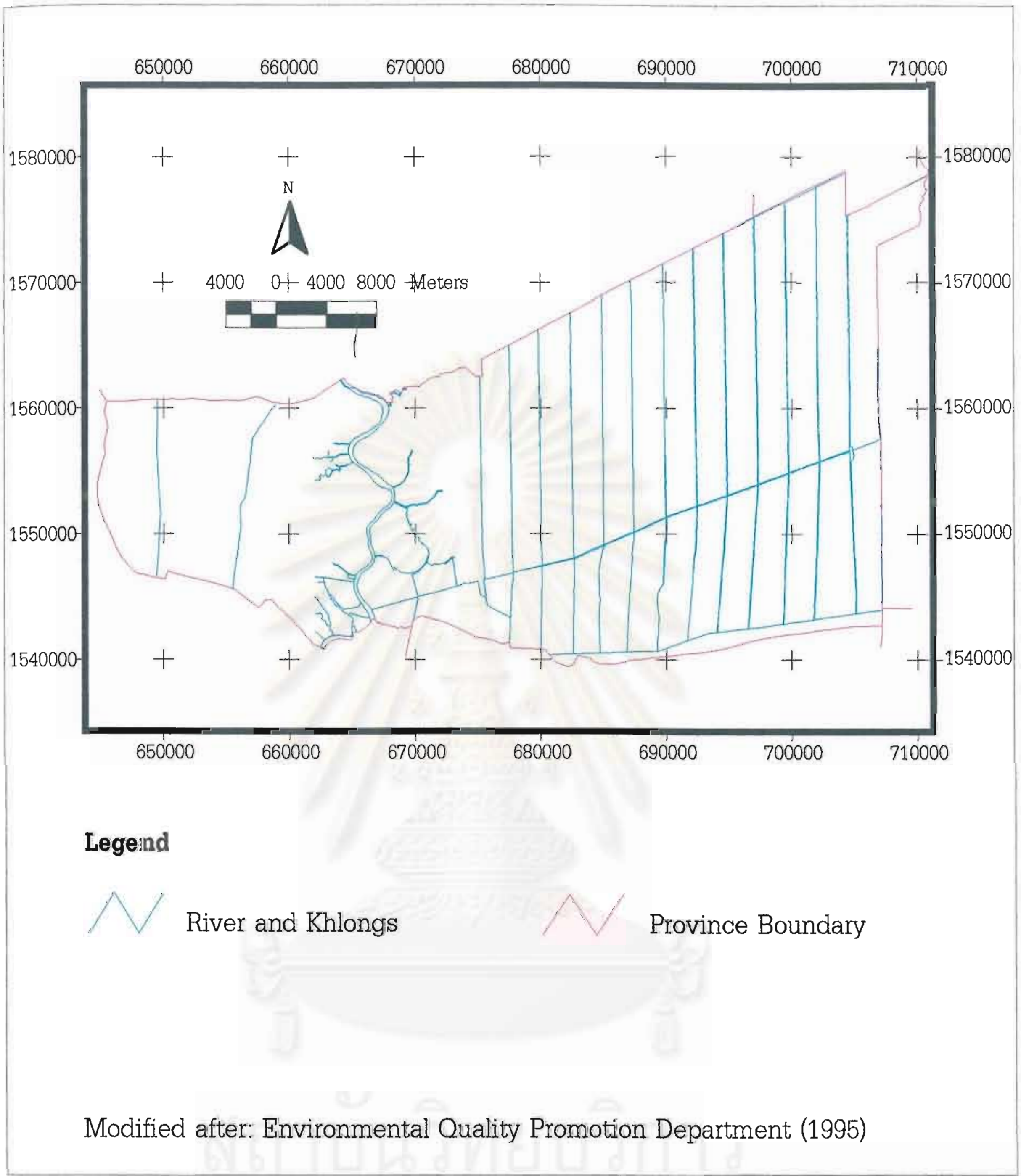
3) Amphoe Lat Lum Kaeo-: Khlong Pra Udom, Khlong Bang Luang, Khlong Lat Lum Kaeo, Khlong Bang Pho, Khlong Sakae, Khlong Rahaeng, Khlong Sam Wa

4) Amphoe Thanyaburi-: Khlong Rangsit Prayunrasak, Khlong Chol Pratan nos.1-13

5) Amphoe Khlong Luang-: Khlong Chol Pratan nos.1-7

6) Amphoe Lumlukka-: Khlong Chol Pratan nos.1-13, Khlong Hok Wa Sai Lang

7) Amphoe Nuangsua-: Khlong Rapeepat, Khlong Chol Pratan nos.8-13



SELECTION OF POTENTIAL SOLID WASTE DISPOSAL AREAS

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Figure 3-3 Surface water system in Pathum Thani province.

3.4.2 Groundwater

Pathum Thani province is a part of the Chao Phraya basin which extends from Nakorn Sawan province to Samut Prakan, south of Bangkok. The groundwater in this basin is divided into (a) extensive and productive aquifers and (b) extensive but less productive aquifers.

In the extensive and productive aquifers, the groundwater system is concealed under the Bangkok marine clay, and is made up of multiple aquifers formed by alternating layers of sand or gravel and clay. To the depth of about 650 meters in Bangkok, 8 principal artesian aquifers have been distinguished according to their hydrogeoelectrical properties, namely:

(a) Bangkok aquifer	depth 50 – 100 m.
(b) Pra Pradaeng aquifer	depth 100 - 140 m.
(c) Nakhon Luang aquifer	depth 150 -180 m.
(d) Nonthaburi aquifer	depth 200 - 250 m.
(e) Sam Khok aquifer	depth 250 - 300 m.
(f) Paya Thai aquifer	depth 250 - 350 m.
(g) Thon Buri aquifer	depth 300 - 420 m.
(h) Pak Nam aquifer	depth 400 - 550 m.

Nakorn Luang, Nontaburi and Pra Pradaeng aquifers are most useful because they have good water quality and quantity. All aquifers have similar water-bearing characteristics and are relatively very permeable. Individual aquifer yields from 500-1,000 gpm. or more other seven aquifers yield relatively good water quality, except in the coastal area where connate saline water exists or salt water enchroachment occurs. The water of inferior quality due to high concentration iron, manganese, and hardness also locally occurs in all aquifers. The sediments beyond the depth of 650 meters are indicated by electrical logs to yield salty water.

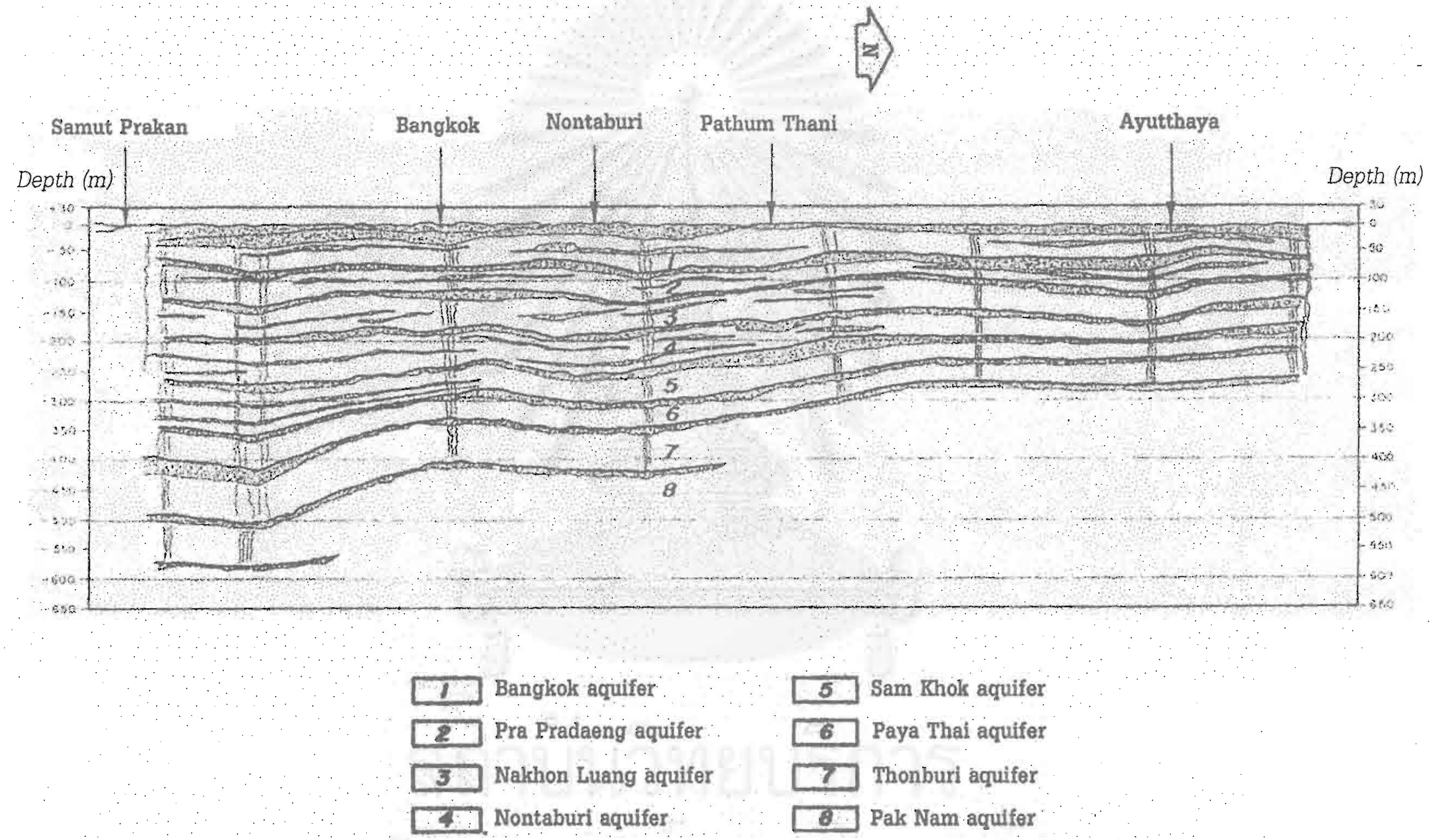
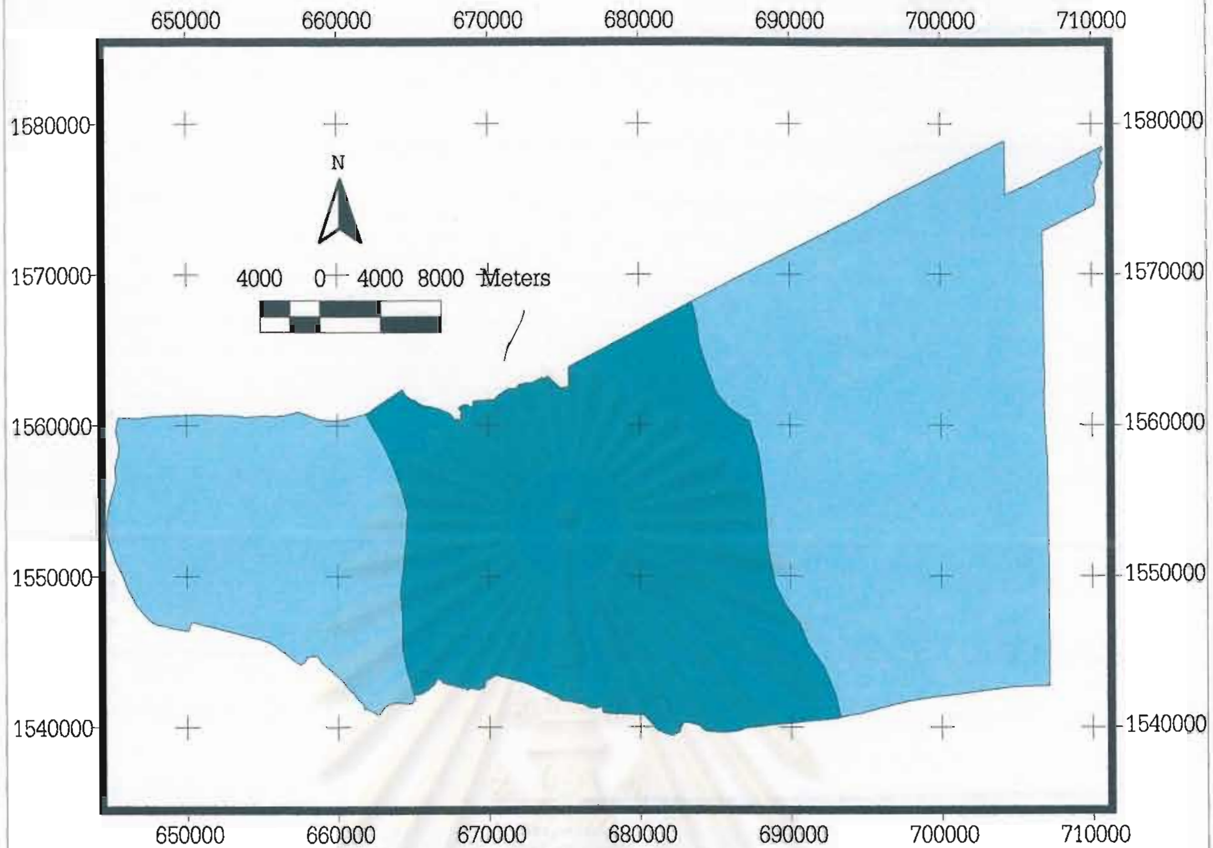


Figure 3-4 Cross-section showing aquifers of the lower central plain of Thailand

The extensive but less productive aquifers in the area are unconsolidated to semiconsolidated sand and gravel in clay matrix, angular grained, poorly to moderately sorted, rather thick sandy to compacted clay beds. They have been found in most parts of the eastern margin of the basin including an elongate area extending from Suphan Buri to east of Samut Sakhon. Lenses of sand and gravel are occasionally intercalated between the thick sandy clay beds but not very productive. The thickness range from tens of meter to more than 200 meters. Due to poorly assortment characteristics and abundant of clay the yields are commonly low with the maximum of 20 gpm. of fresh water with high iron content. Considerable quantity of brackish groundwater may be available in most areas.

Due to the extensive aquifers are in the study area. There are many groundwater wells scatter in the province. There are 50 groundwater wells in year 1992 and continuously increases up to date.



Legend

Extensive and productive aquifers

Extensive but less productive aquifers

Source: Department of Mineral Resources (1976)

SELECTION OF POTENTIAL SOLID WASTE DISPOSAL AREAS

IN PATHUM THANI PROVINCE

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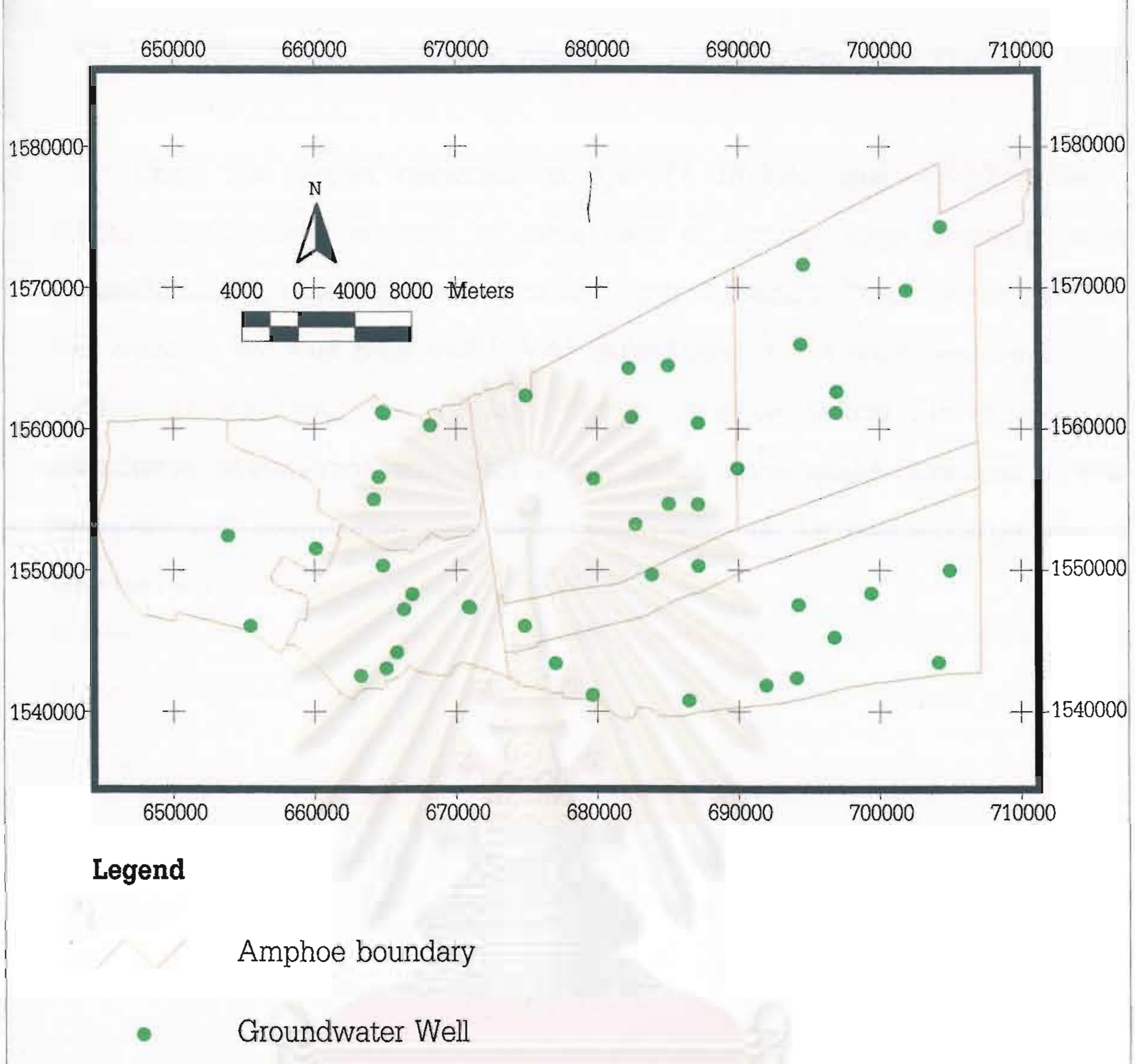
Figure 3-5 The hydrogeological map of the lower central plain of Thailand.



Source: Department of Mineral Resources (1992)

SELECTION OF POTENTIAL SOLID WASTE DISPOSAL AREAS

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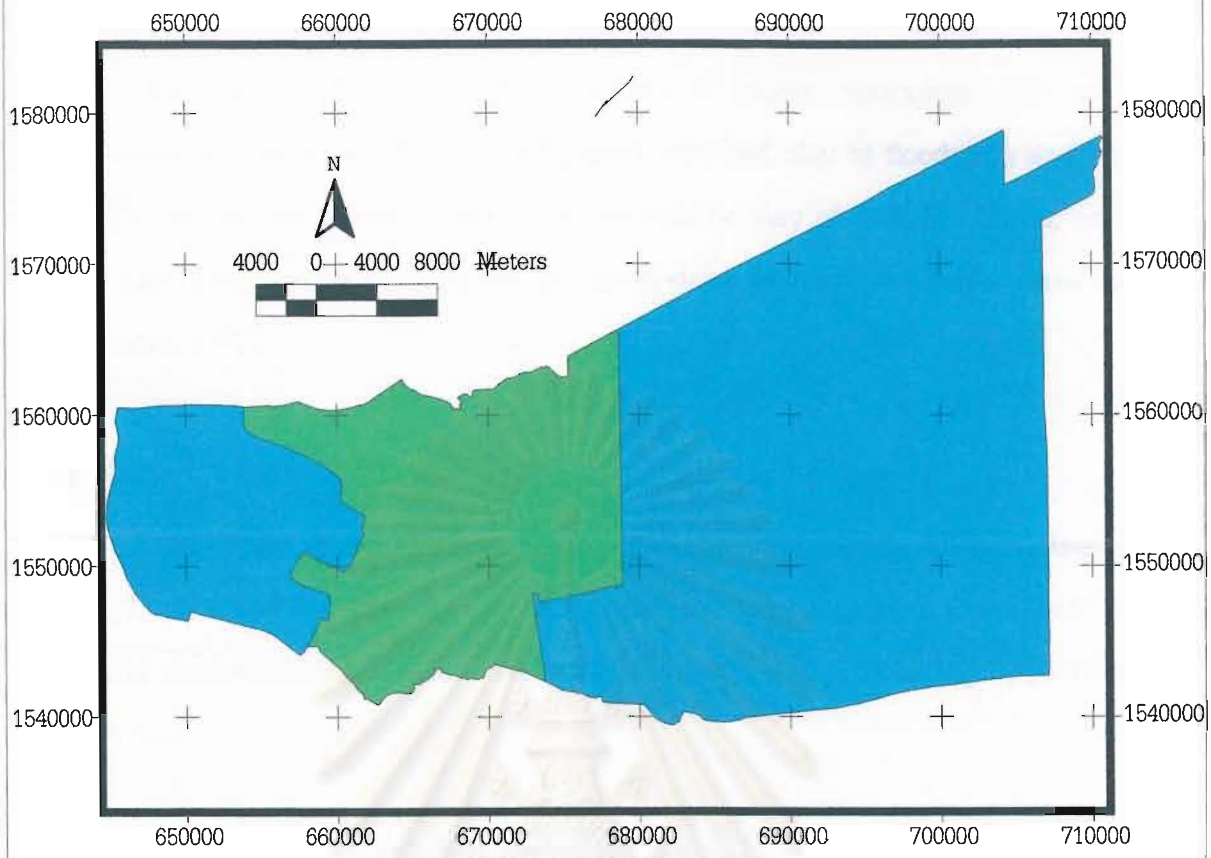
Figure 3-6 The ground water wells map of Pathum Thani province.

3.4.3 The Water Conservation Area for the Metropolitan Water Supply

Under the cabinet resolution on April 17, 1979,the area extending from Phra Nakorn Sri Ayutthaya province to some parts of Pathum Thani province (about 95 squarekilometers); covering the area in the north of Pathum Thani's town plan (Stripes from canal on the east bank and Khlong Bang Luang in the west bank) and including Tambon Khlong Nung and Khlong Song in Amphoe Khlong Luang now, is the groundwater conservation area. This is due to the water quality problems in Bangkok Metropolis and neighboring area as a consequence of the over-recharge from many factories near the Chaopraya river since 1987.



Legend

Water conservation area for the metropolitan water supply

Non-conservation area for water supply

Source: Pathum Thani Provincial Office (1999)

SELECTION OF POTENTIAL SOLID WASTE DISPOSAL AREAS

IN PATHUM THANI PROVINCE

Miss Kamolporn Kerdput

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Figure 3-7 The water conservation area map.

3.5 Geology

The area of Pathum Thani province is rather homogeneously underlain by Quaternary sediments of alluvial gravel, sand, silt, and clay of floodplain and backswamp deposits. Below the fluvial sediments is the marine clay of tidal-flat origin, and the very thick succession of several cycles of fluvial-delta sediments. (Department of Mineral Resources, 1977)

3.6 Soil

Most of the area in Pathum Thani province is floodplain characterized by clayey with pH of about 6-4 that can be further divided into 2 groups. Good farm soil group: covering approximately 30% and very acid farm soil group: covering approximately 70% of the area.

Due to the main characteristics of acid clayey soil, this condition is relatively unsuitable for farming and cropping, and requires marl with chemical fertilizer to improve the soil quality.

Pathum Thani is located in the floodplain area, and the underlying sediments are originated from at least 2 sources:

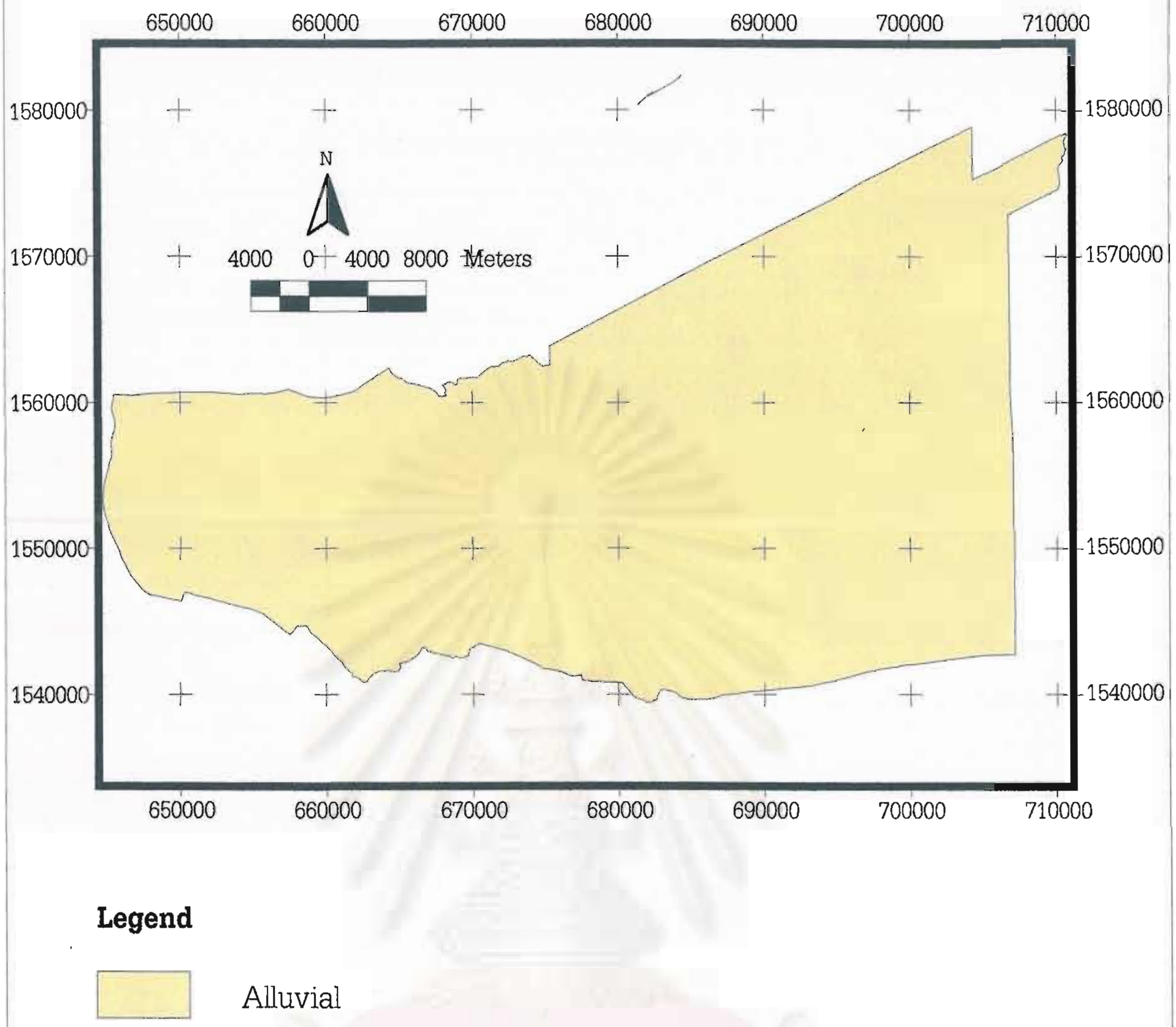
The upper most sediments are originated from the fluvial sediment of Chao Phraya floodplain and backswamp deposits of silt and clay. Underlying the floodplain and backswamp deposits are brackish clay of tidal flat origin.

With regard to the soil classification, the Pathum Thani province is underlain by 15 soil series. The detailed characteristics of each soil series are presented in Table3-2, and the distribution of these soil series are illustrated in Figure 3-8. (Department of Land Development, 1972)

Table 3-2 Summary of soil characteristics of 15 soil series of Pathum Thani province.

Soil series, phase or variant	Mapping Unit No.	Slope (%)	Soil Depth (cm)	Texture Profile	Permeability
Bangkok**	7	<1	>150	clay throughout	slow
Bang Len, overwash phase**	10	1 or less	>150	clay throughout	slow
Thon Buri**	14	ridged	>150	clay throughout	slow
Bang Nam Prieo*	18	<1	>150	clay throughout	slow
Chachoengsao*	19,20	<1	>150	clay or silty clay loam over clay	slow
Bang Khen*	21	1 or less	>150	clay or silty clay over clay	slow
Bang Khen, overwash phase*	22	1 or less	>150	clay or silty clay over clay	slow
Ayutthaya*	25	<1	>150	clay or silty clay over clay	slow
Rangsit*	28	<1	>150	clay throughout	slow
Rangsit,very acid phase*	29	<1	>150	clay throughout	slow
Thanyaburi*	31	<1	>150	clay throughout	slow
Sena*	32	<1	>150	clay throughout	slow
Ongkharak*	34	<1	>150	clay or silty clay over clay	slow
Don Muang*	35	<1	>150	sandy clay, clay loam or clay over loam or sandy clay loam over clay below 150 cm.	slow
Bang Pa-in*	40	1 or less	>150	clay or silty clay throughout	slow
Undifferentiated ridged acid*	37				

Source: Soil survey division,Bangkok 1972.



Source: Department of Mineral Resources (1982)

SELECTION OF POTENTIAL SOLID WASTE DISPOSAL AREAS

IN PATHUM THANI PROVINCE

Miss Kamolporn Kerdput

Inter-Department of Environmental Science

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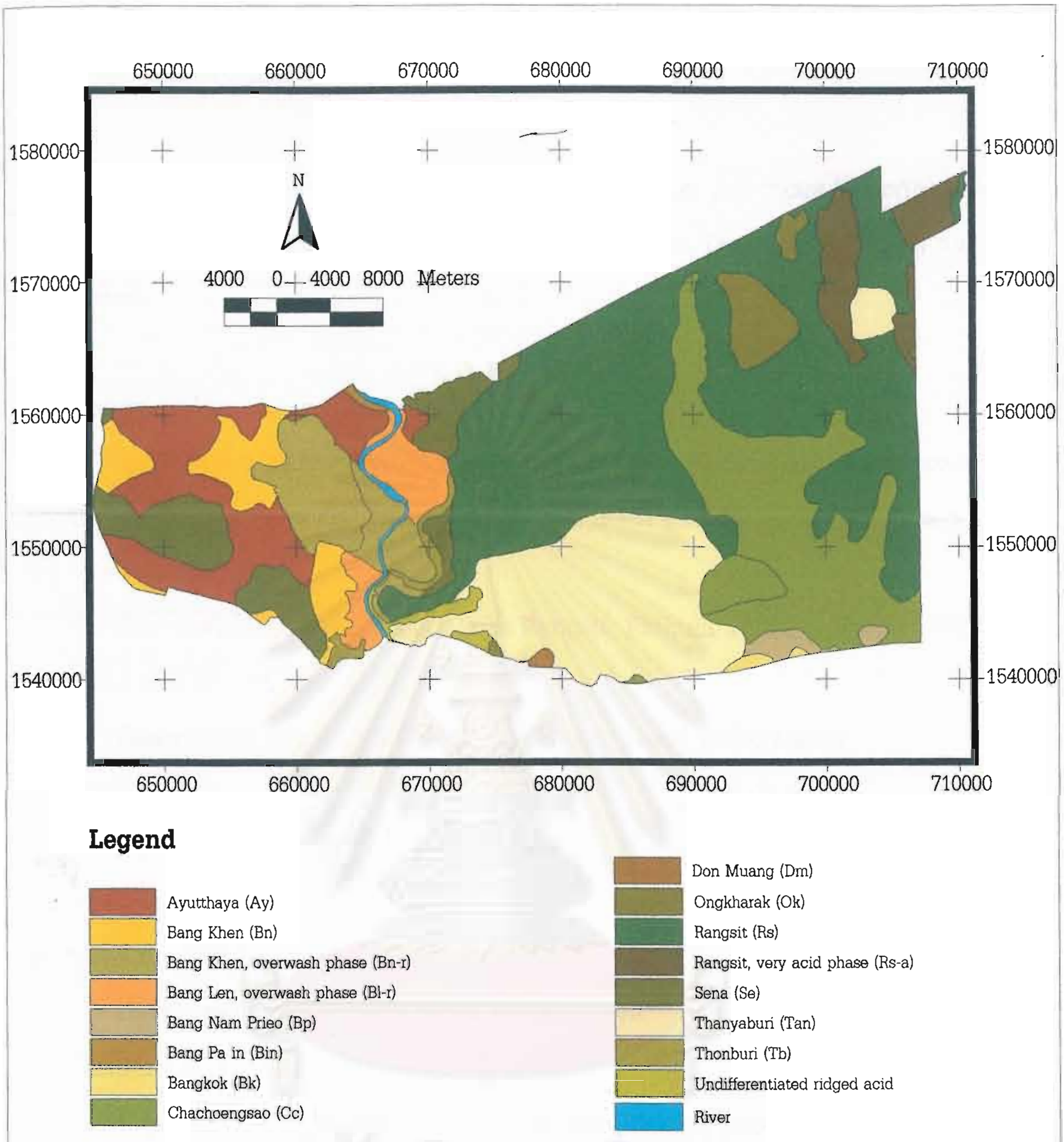
Figure 3-8 The geological map of Pathum Thani province.



Source: Land Development Department (1972)

Figure 3-9 The soil map of Pathum Thani province.

3.7 Transportation

Pathum Thani is a by pass from Bangkok to other provinces in northern and northeastern Thailand. There are many roads in Pathum Thai, and the main roads are as follows:

(a) National highway no.1 (Paholyotin Rd.)

Paholyotin road starts from the Victory Monument, Bangkok and passes through Pathum Thani, Saraburi and other provinces to north and norteasthern Thailand.

(b) Road no.305

This road,88 kilometers long, links Rangsit, Pathum Thani to Nakorn Nayok.

(c) Road nos.306, 307 and 345

These roads link Amphoe Muang, Pathum Thani to Nontaburi.

(d) Road no.346

This road links Amphoe Lat Lum Kaeo, Pathum Thani to Kumpeangsan, Nakorn Patom.

(e) Road nos.347,3111 and 3309

These roads link Pathum Thani to Ayutthaya.

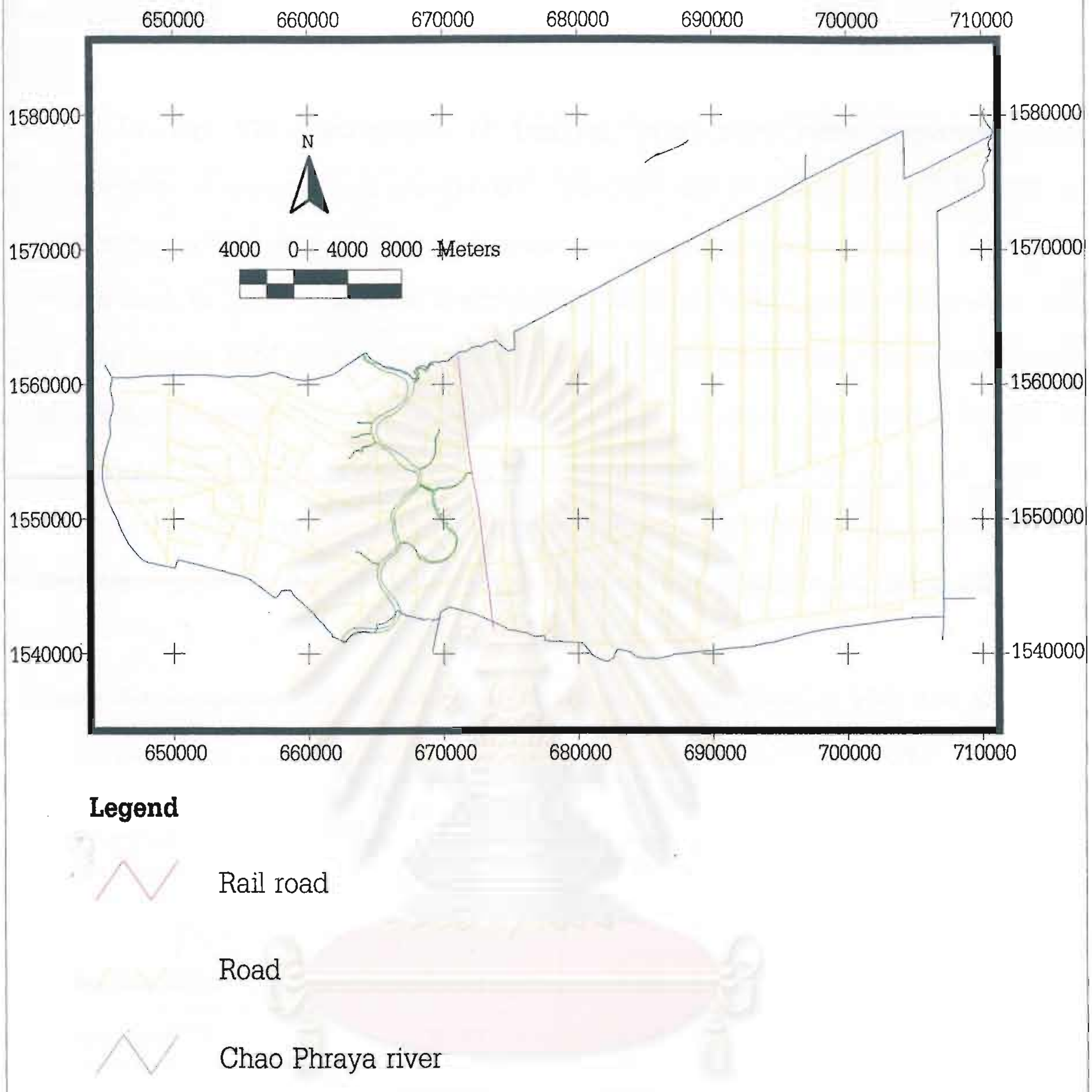
(f) Road no.3312

This road links Pathum Thani to Meanburi district, Bangkok.

The highway and road network of Pathum Thani province is presented in Figure3-9.

In addition to the existing highway and road network, the Pathum Thani province is linked by the northern and northeastern railroad extending from Bangkok.

With respect to the in-land water way transportation, the navigation system along the Chao Phraya river is the main transportation route linking Pathum Thani to other provinces both in the upstream and downstream areas.



Modified after: Environmental Quality Promotion Department (1995)

Figure 3-10 The transportation network of Pathum Thani province.

3.8 Land Use

Landsat TM photographs of Pathum Thani have been employed in the interpretion of existing land use pattern. The land use of Pathum Thani in 1988 and 1999 are classified into 4 types as agricultural land, built-up area, water bodies, and barren land. In 1988, most area is agricultural land of 1123.03 square kilometers. Built-up area covers 25.64 square kilometers or about 1.71 % of total area, Water bodies cover 115.38 square kilometers, and barren area covers 233.47 square kilometers. In 1999, the agricultural land and the built-up area increase in many percentages, Whereas the water bodies and the barren land decrease, respectively. The changing proportion of land use patterns of Pathum Thani are summarized and presented in Table 3-3.

Table 3-3 Comparison of the land use pattern in Pathum Thani in 1988 and 1999.

Land Use	1988		1999	
	Area (km^2)	%	Area (km^2)	%
Agricultural land	1123.03	74.99	1370.99	91.55
Built-up area	25.64	1.71	68.41	4.57
Water bodies	115.38	7.70	47.41	3.17
Barren land	233.47	15.60	10.70	0.71
Total	1497.52	100	1497.51	100

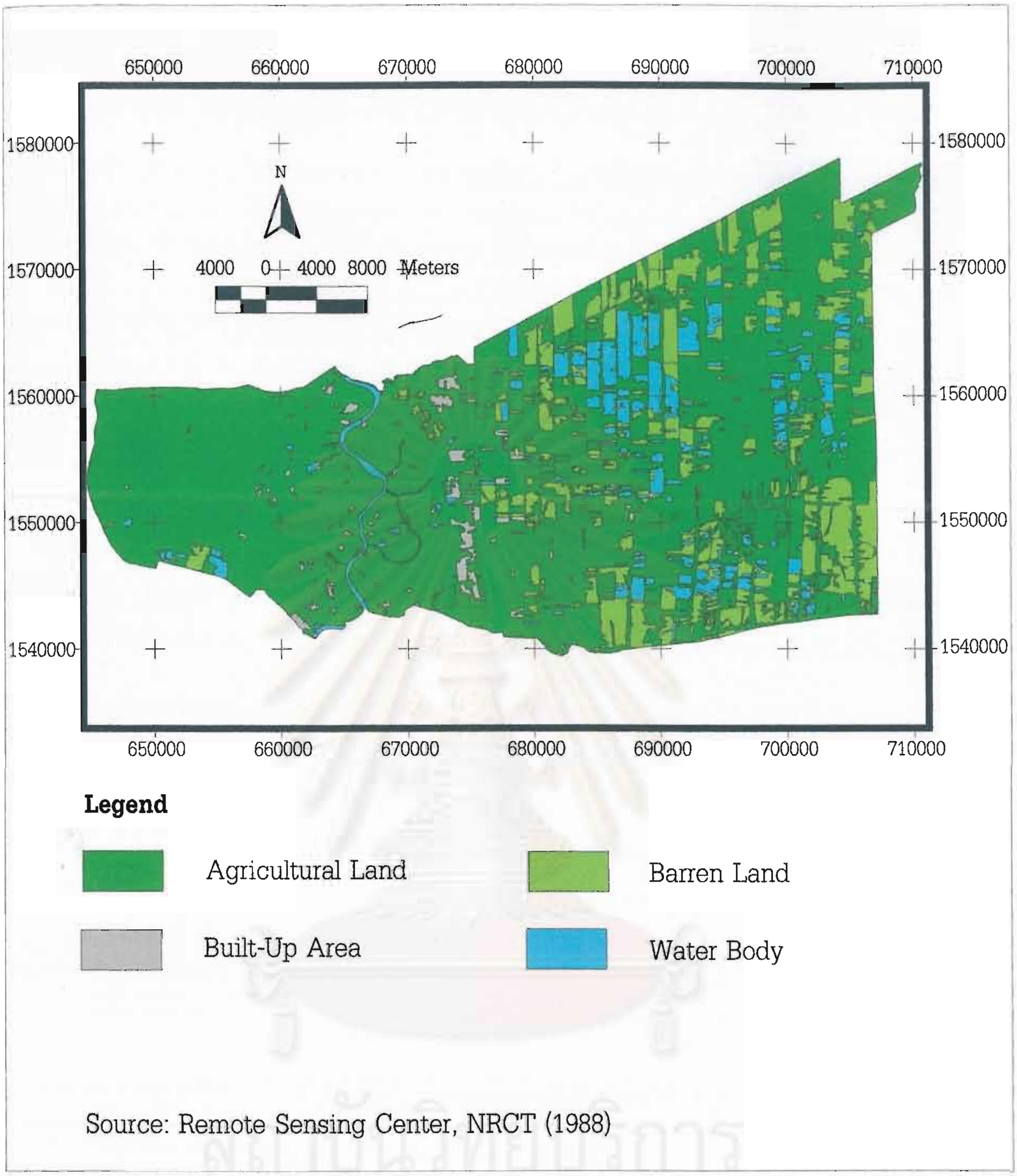
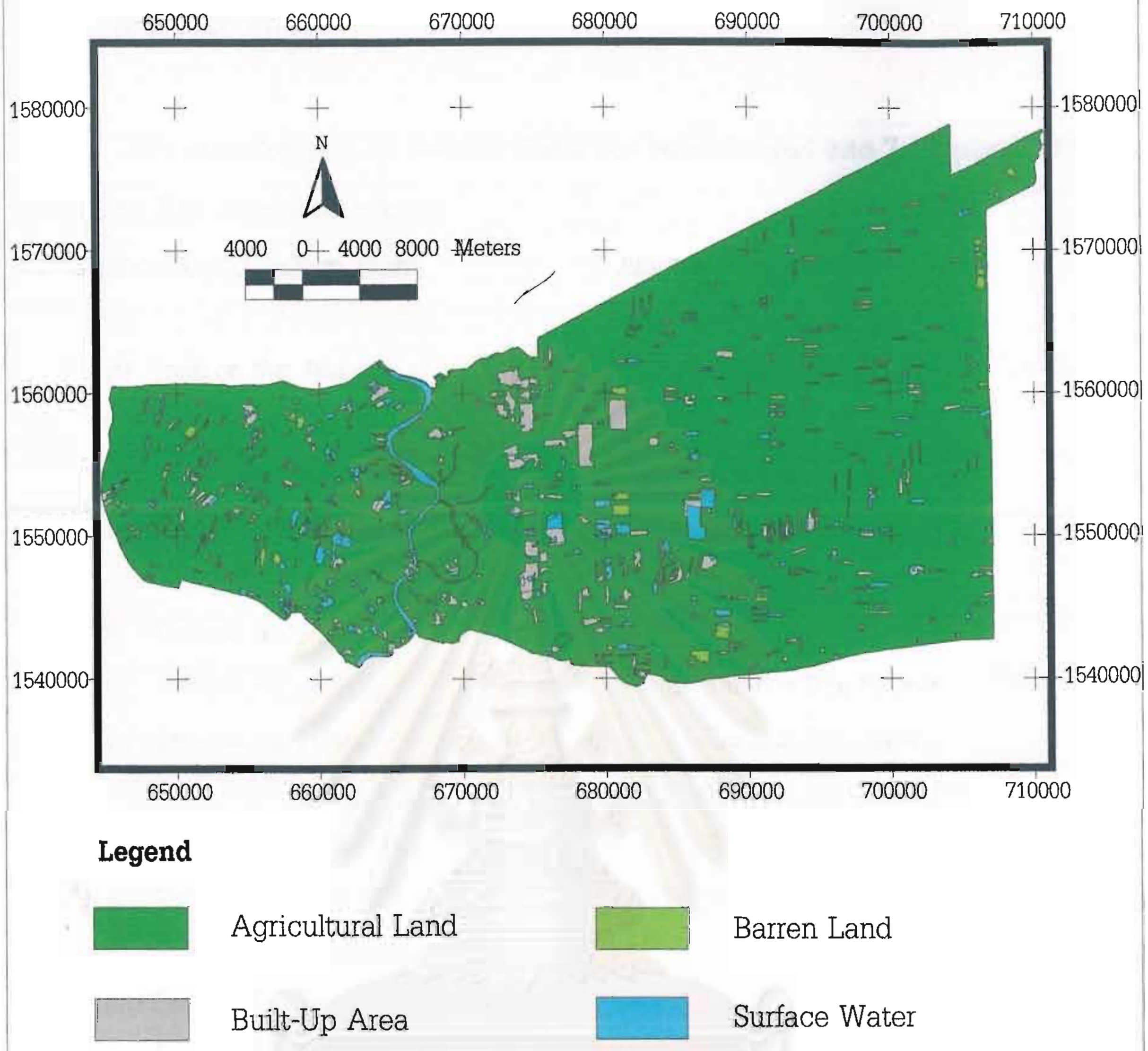


Figure 3-11 The land use map of Pathum Thani province in 1988.



Source: Remote Sensing Center, NRCT (1999)

SELECTION OF POTENTIAL SOLID WASTE DISPOSAL AREAS

IN PATHUM THANI PROVINCE

Miss Kamolporn Kerdput

Inter-Department of Environmental Science

Graduate School, Chulalongkorn University

Figure 3-12 The land use map of Pathum Thani province in 1999.

3.9 Administration

The administration of Pathum Thani has been divided into 7 Amphoes, 60 tambons, 529 villages as follows:

1. Amphoe Muang Pathum Thani

(a) Tambon Ban Mai
(b) Tambon Ban Klang
(c) Tambon Ban Chang
(d) Tambon Ban Krachaeng
(e) Tambon Bang Kayang
(f) Tambon Bang Khu Wat
(g) Tambon Bang Luang
(h) Tambon Bang Dua
(i) Tambon Bang Pud
(j) Tambon Bang Phun
(k) Tambon Bang Kradi
(l) Tambon Suanprigthai
(m) Tambon Luk Hok
(n) Tambon Bang Praog

2. Amphoe Sam Khok

(a) Tambon Bang Toei
(b) Tambon Khlong Khwai
(c) Tambon Sam Khok
(d) Tambon Krachaeng
(e) Tambon Bang Pho Nua
(f) Tambon Chiang Rak Yai
(g) Tambon Ban Pathum
(h) Tambon Ban Ngiw
(i) Tambon Chiang Rak Noi
(j) Tambon Bang Krabu
(k) Tambon Thai Ko

3. Amphoe Thanyaburi

(a) Tambon Prachatipat
(b) Tambon Bungyeeto
(c) Tambon Rangsit
(d) Tambon Lumpakkud
(e) Tambon Bungsanan
(f) Tambon Bungnumrag

4. Amphoe Lumlukka

(a) Tambon Kukod
(b) Tambon Ladsawai
(c) Tambon Bungkumproi
(d) Tambon Lumlukka
(e) Tambon Bungthonglang
(f) Tambon Lumsai
(g) Tambon Bungkohai
(h) Tambon Peetchudom

5. Amphoe Khlong Luang

(a) Tambon Khlong Nung
(b) Tambon Khlong Song
(c) Tambon Khlong Sam
(d) Tambon Khlong See
(e) Tambon Khlong Ha
(f) Tambon Khlong Hok
(g) Tambon Khlong Chet

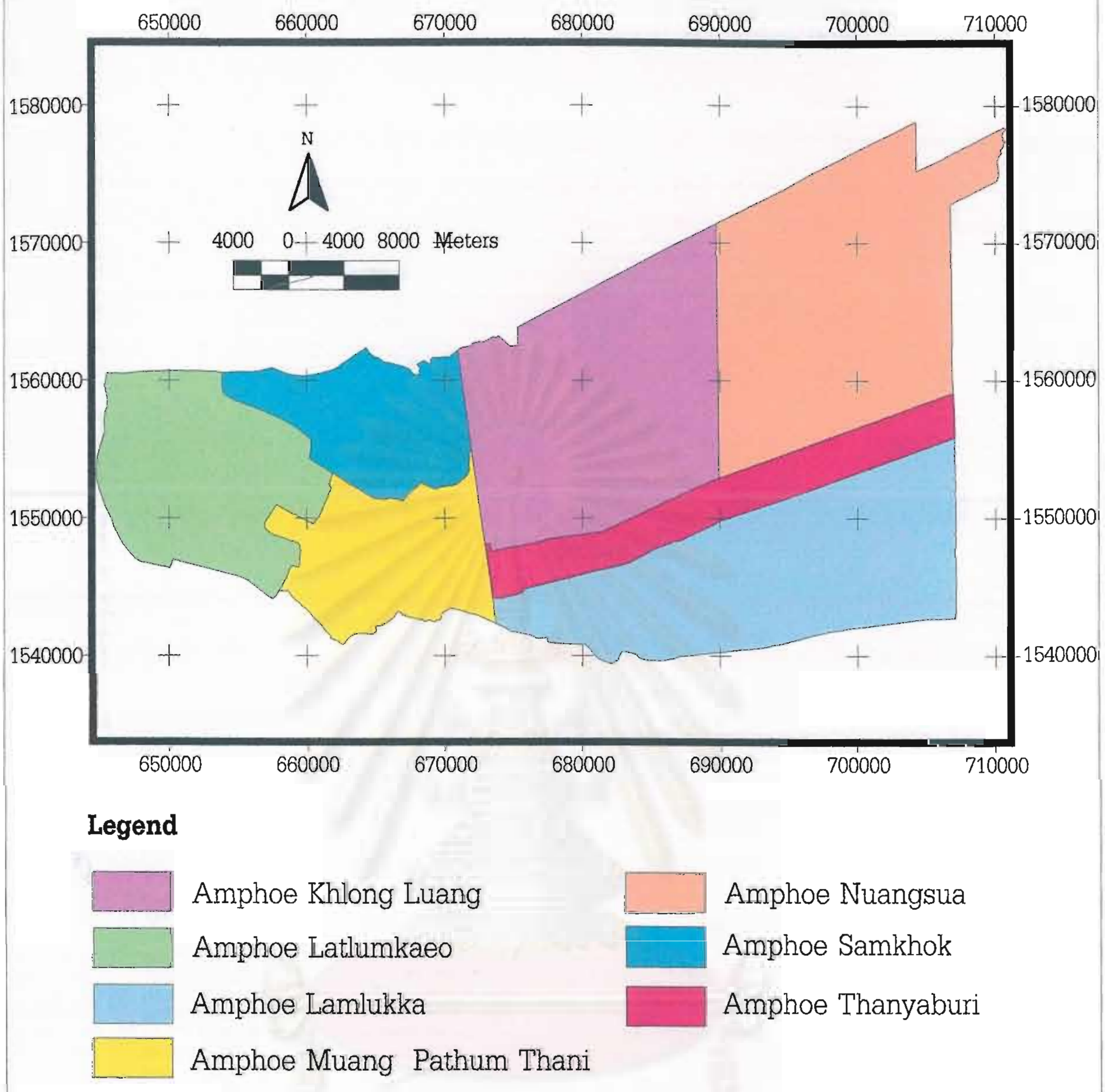
6. Amphoe Nuangsua

(a) Tambon Bungba
(b) Tambon Bungbon
(c) Tambon Bungkasam
(d) Tambon Bungchumor
(e) Tambon Nuangsamwang
(f) Tambon Salakru
(g) Tambon Nopparat

7. Amphoe Lat Lum Kaeo

(a) Tambon Rahaeng
(b) Tambon Lat Lum Kaeo
(c) Tambon Khu Bang Luang
(d) Tambon Khu Khwang
(e) Tambon Khlong Pra Udom
(f) Tambon Bor Ngen
(g) Tambon Na Mai

The local administration are classified as Changwat administration, municipality, Tambon administration, and Tambon-council, respectively in decreasing hierarchy.



Source: Royal Thai Survey Department (1982)

SELECTION OF POTENTIAL SOLID WASTE DISPOSAL AREAS

IN PATHUM THANI PROVINCE

Miss Kamolporn Kerdput

Inter-Department of Environmental Science

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Figure 3-13 The administration map of 7 Amphoes in Pathum Thani province.

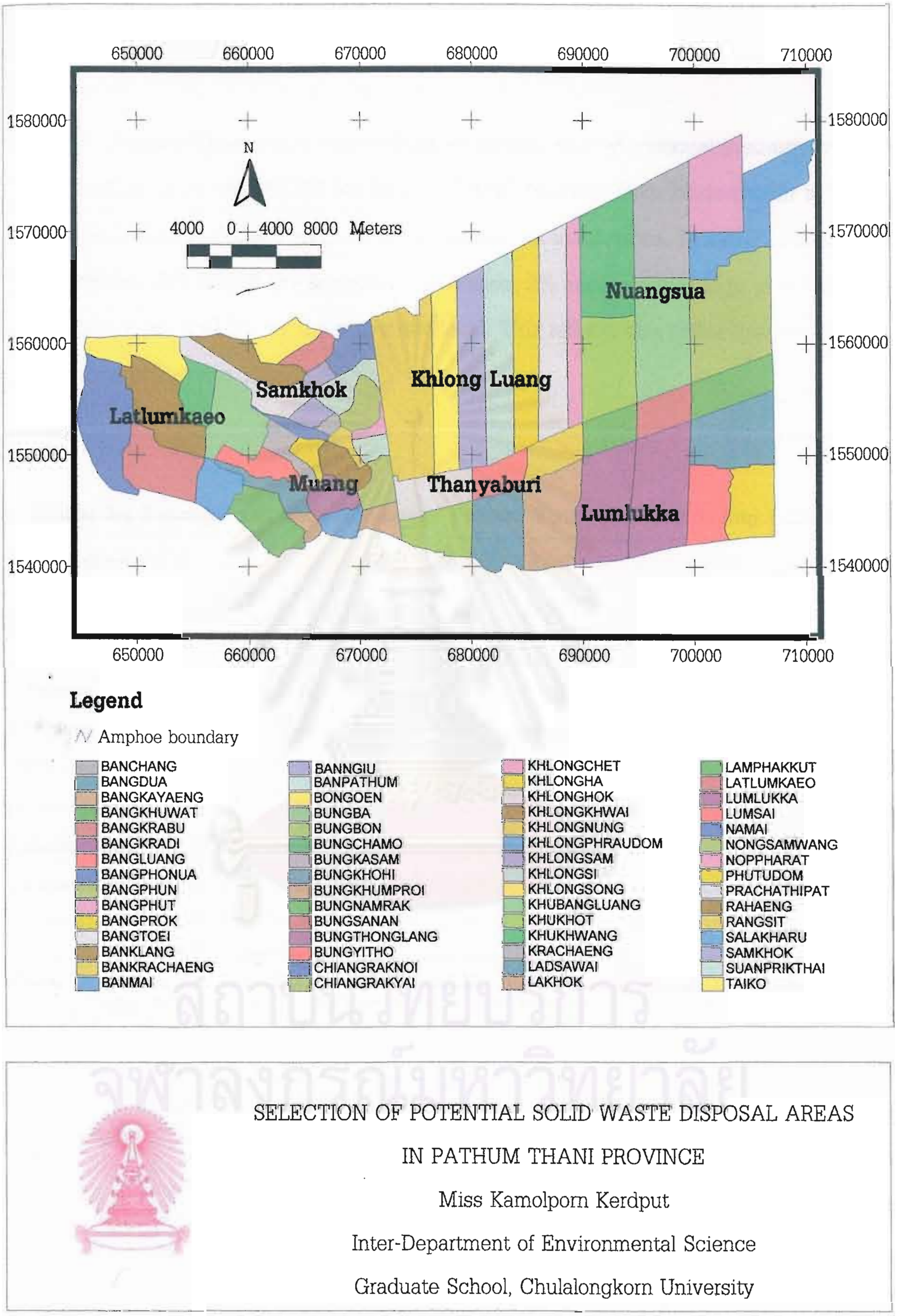


Figure 3-14 The administration map of 60 Tambons in Pathum Thani province.

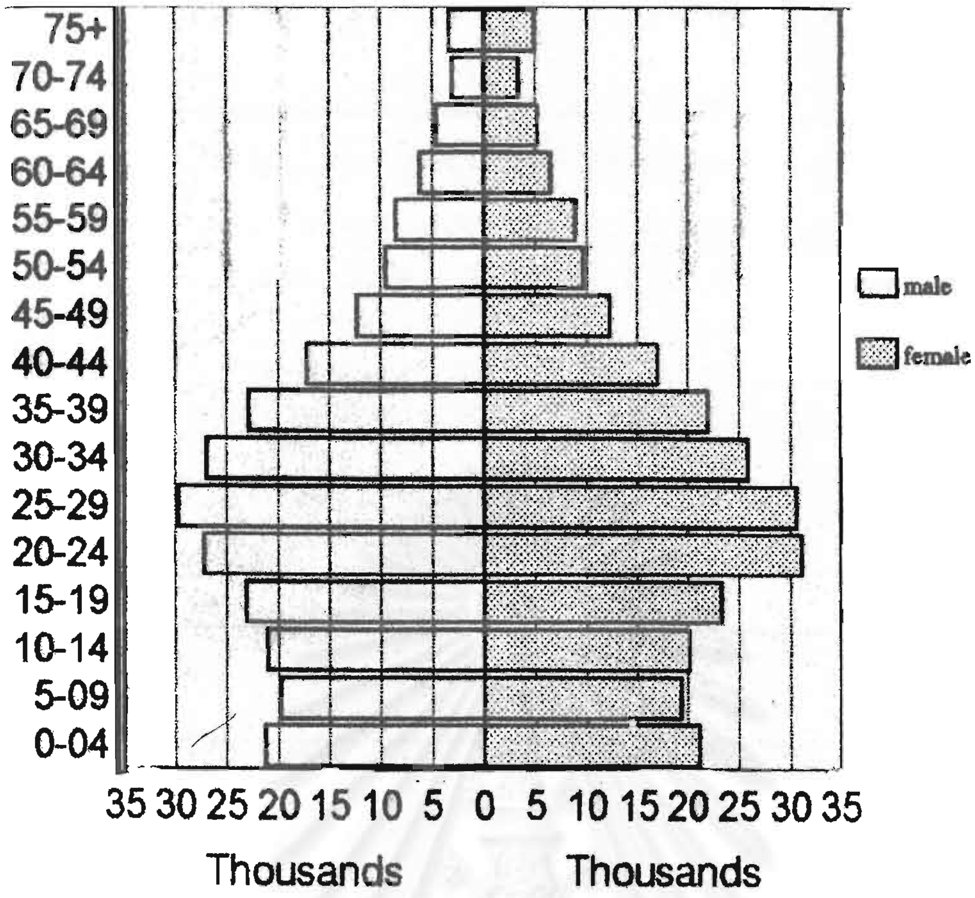
3.10 Population

Pathum Thani has a wide variety of schools and educational institutions. Alltogether there are 163,550 students and 8,408 teachers from kindergarten to university levels. Among all number of educational institutions, 73% are for the primary education, 22% are for the secondary education, 2% are for senior high school to diploma level, and 3% for the university level. This reflects the better quality of human resource of Pathum Thani.

Table 3-4 Population of each Amphoe of Pathum Thani province during 1981-1997.

Amphoe	YEAR								
	1981	1983	1985	1987	1989	1991	1993	1995	1997
1.Muang Pathum Thani	67,088	71,053	71,560	82,876	89,059	94,604	103,878	97,612	123,527
2.Khlong Luang	59,838	63,079	63,215	72,180	77,479	82,080	87,550	95,371	104,915
3.Thanyaburi	54,506	59,387	62,903	75,679	81,130	84,916	90,872	97,988	111,021
4.Nuangsua	34,145	34,533	34,982	38,392	39,694	40,490	41,784	43,031	44,663
5.Latlumkaew	29,636	31,365	31,594	34,341	35,083	35,393	37,507	38,458	40,395
6.Lumlukka	50,932	62,261	64,180	73,158	80,690	89,235	98,974	111,158	125,176
7.Sam Khok	35,966	36,141	36,251	38,567	38,795	39,250	39,521	40,633	42,631
Total	**332,111**	**357,819**	**364,685**	**415,193**	**441,930**	**465,968**	**500,086**	**524,251**	**592,328**

Source: Department of Provincial Administration (1993)



Source: Department of Provincial Administration (1993)

Figure 3-15 The pyramid age structure of population of Pathum Thani in 1995.

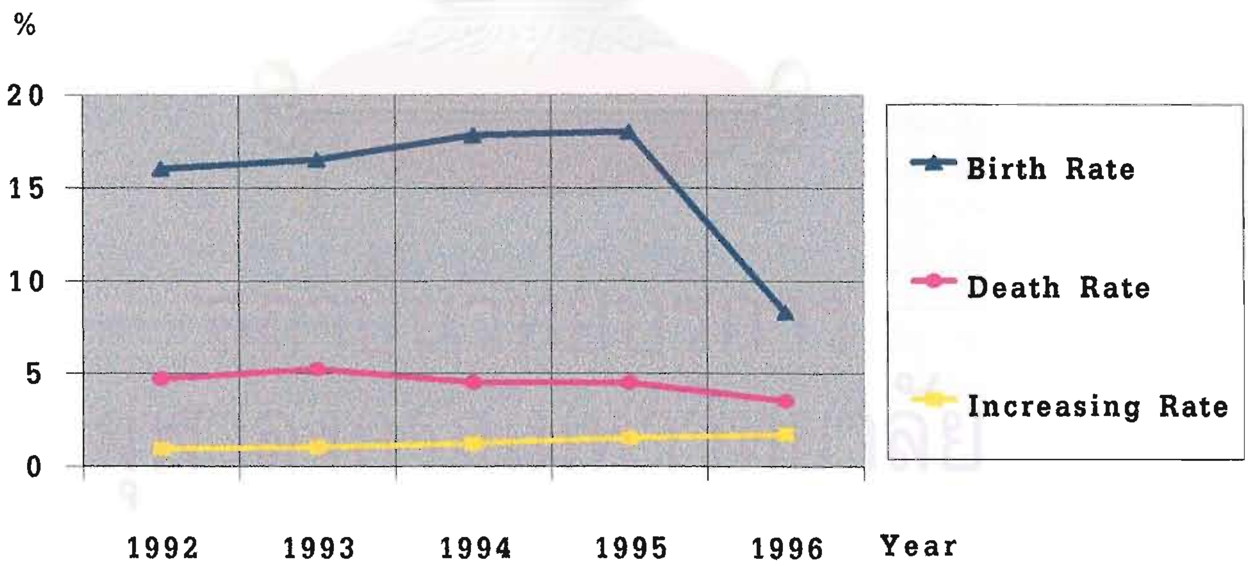
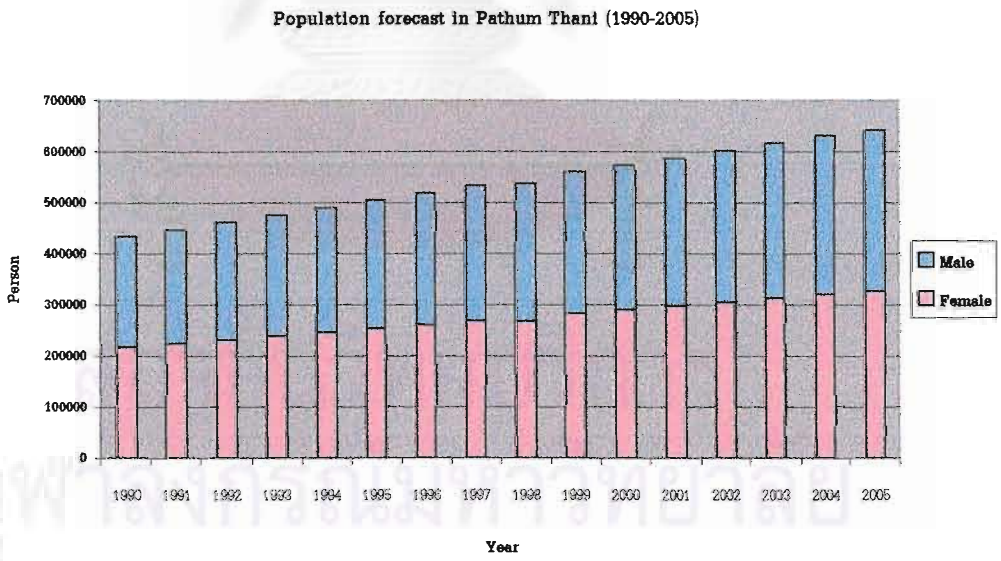


Figure 3-16 The birth rate, death rate, and population increasing rate of Pathum Thani during 1992-1996.

Table 3-5 Population forecast projection of Pathum Thani province.

Amphoe	Total population (person)		Urban population (person)				Increasing	
	1990	2010	1990	%	2010	%	increasing population (person)	%
1.Muang Pathum Thani	80,016	159,918	44,809	56.0	156,630	97.9	111,821	249.6
2.Khlongluang	86,375	171,639	54,371	62.9	160,869	93.7	106,498	195.9
3.Tanyaburi	76,219	160,319	45,693	59.9	137,610	85.8	91,917	201.2
4.Nuangsua	33,353	62,353	2,349	7.0	6,440	10.3	4,091	174.2
5.Ladlumkaew	30,089	56,084	16,618	55.2	29,816	53.2	13,198	79.4
6.Lumlukka	75,604	165,012	40,792	54.0	142,707	86.5	101,915	249.8
7.Samkok	30,751	55,318	12,377	40.2	32,648	59.0	20,271	163.8
Total	**412,407**	**830,643**	**217,009**	**52.6**	**666,720**	**80.3**	**449,711**	**207.2**

Source : The Office of National Economic and Social Development Board



Source : The Office of National Economic and Social Development Board and Thailand Development Research Institute.

Figure 3-17 Forecasting of population of Pathum Thani (1990-2005)

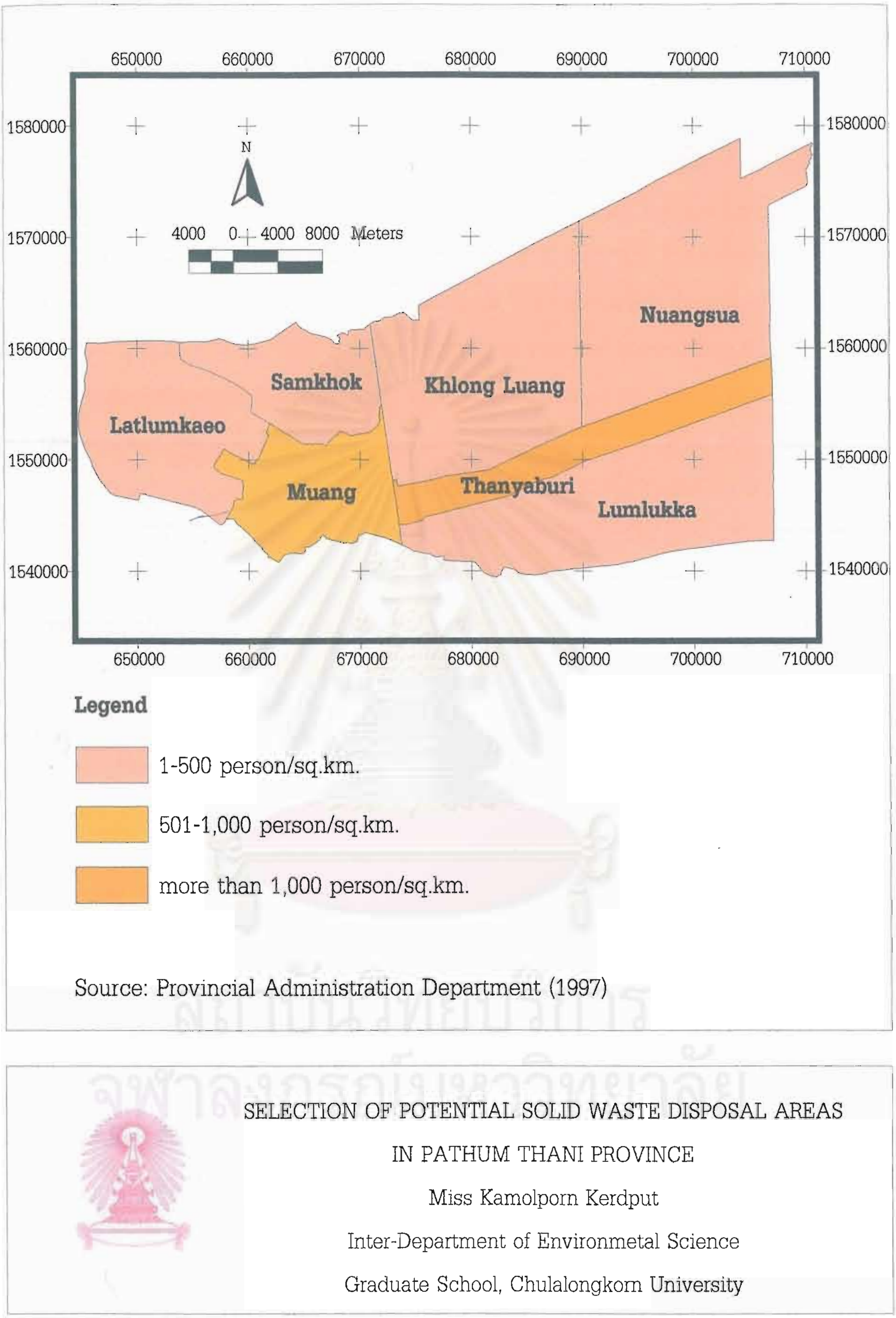


Figure 3-18 The population density map of Pathum Thani in 1997.

3.11 Socio-economic Conditions

The economic structure in Pathum Thani under the present study included agricultural sector, industrial sector, and commercial sector. For the agricultural sector, the agricultural land is 582,881 rai or 62.67% of total area. The main economic crop is rice. Other economic crops are critus sinensis, the vegetables, the mango, and the banana. Besides, there are numerous farming animal and aquaculture through out the province. For industrial sector, there is a rapid expansion since 1988 after the government policy to promote the industry. Besides, Pathum Thani is a suitable area for industrial development due to the close proximity to the capital, port, with convenient transportation, and relatively lower land price. The area with greatest number of factories is Amphoe Khlong Luang. With regard to the commercial sector, there is only a sligthly growth up to the present with four large markets for agricultural produces.

Along with the population growth the economic condition of Pathum Thani increased from 1986 to 1996. Both Gross Provincial Product and per Capita Income are increasing annually. Pathum Thani has a high economic expanding rate in 1994 with the average income per person of 200,455 baht/year. This level is the second highest in Thailand. Gross Provincial Product value is 98,428.5 million baht depending on the industrial sector of totally 73%. (Office of the National Economic and Social Development Board,--)

Table 3-6 Comparison of average monthly income and average monthly expenditures per household in Pathum Thani (1994).

Average household size	Total Income (฿)	Income per person (฿)	Total expenditures (฿)	Expenditures per person (฿)
4.1	13,932	3,398	11,308	2,758

Source: The National Statistical Office.

Table 3-7 Gross Regional Product (GRP.) and Gross Provincial Product (GPP.) of Bangkok and its vicinities by Changwat : 1986-1996.

Unit : Million baht

REGION AND CHANGWAT	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Bangkok Metropolis	407,907.7	480,857.8	582,821.4	706,099.7	884,434.2	1,010,678.9	1,148,405.0	1,329,146.6	1,470,800.0	1,642,739.7	1,797,808.8
Samut Prakan	48,349.8	61,519.0	84,985.6	101,491.4	126,083.2	135,821.6	133,366.8	137,956.0	153,004.5	179,400.9	192,638.7
Pathum Thani	28,781.4	32,814.9	35,243.4	42,463.3	47,559.3	56,192.5	61,569.1	76,778.8	98,428.5	119,307.4	127,975.7
Samut Sakhon	16,179.2	19,514.6	22,951.1	27,437.5	30,175.8	37,335.3	48,227.9	55,851.7	73,659.7	82,986.2	87,320.8
Nakhon Pathom	14,658.5	16,419.4	18,654.2	20,710.7	22,878.9	26,834.7	33,393.4	39,772.7	53,961.1	63,076.9	66,770.4
Nonthaburi	14,776.2	17,266.1	21,211.3	32,341.5	37,993.0	41,010.6	45,416.8	54,087.5	58,347.2	73,835.2	81,759.9
Bangkok and Vicinities	530,652.90	628,391.9	765,774.0	930,544.2	1,149,124.4	1,307,873.6	1,470,379.0	1,693,593.3	1,906,201.0	2,161,346.3	2,354,274.3

Source : Office of the National Economic and Social Development Board.

Compiled by : Statistical Data Bank and Information Dissemination Division, National Statistical Office.

Table 3-8 Per Capita GRP. and GPP. of Bangkok and its vicinities by Changwat : 1986-1996.

Unit : Baht

REGION AND CHANGWAT	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Bangkok Metropolis	71,802	82,878	98,383	116,886	142,674	159,212	176,814	200,293	216,932	237,424	254,611
Samut Prakan	72,164	87,385	113,009	129,619	155,466	163,247	156,167	157,125	169,816	194,367	203,635
Pathum Thani	73,798	81,629	85,750	101,587	109,584	125,710	133,556	160,962	200,465	236,252	246,581
Samut Sakhon	50,719	60,045	70,420	83,144	89,278	107,595	135,092	151,771	194,867	213,332	218,849
Nakhon Pathom	24,109	26,961	30,685	33,952	34,508	39,347	47,569	55,011	72,626	82,453	85,058
Nonthaburi	28,916	31,974	37,542	54,631	62,798	65,828	70,743	81,827	82,864	105,479	113,713
Bangkok and Vicinities	64,872	74,960	89,220	106,052	126,975	140,950	154,598	173,827	191,136	211,876	225,743

Source : Office of the National Economic and Social Development Board.

Compiled by : Statistical Data Bank and Information Dissemination Division, National Statistical Office

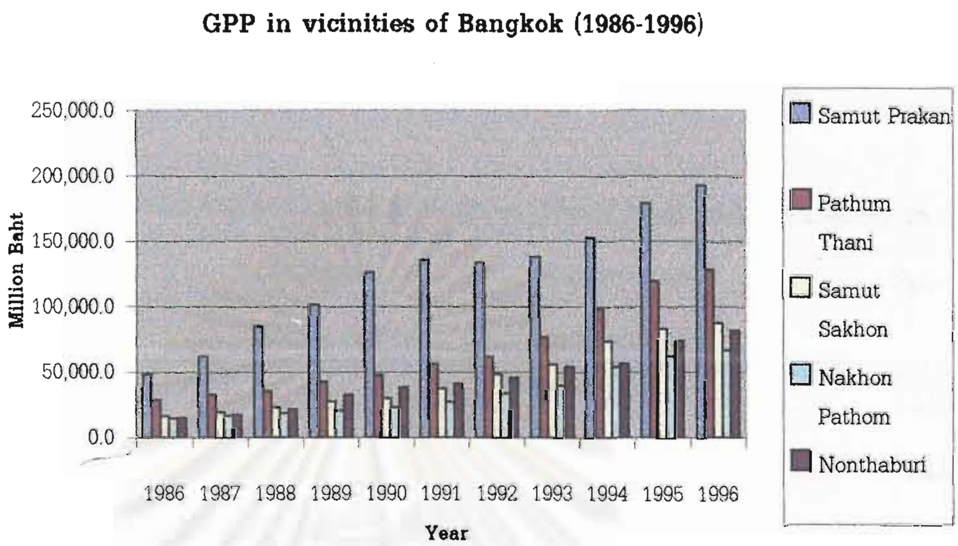


Figure 3-19 Gross Provincial Product in the vicinities of Bangkok 1986-1996

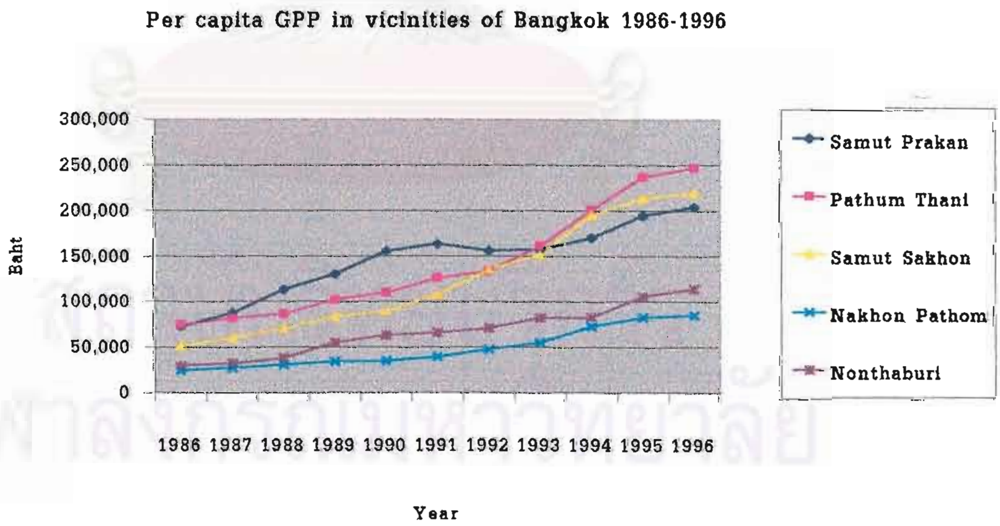


Figure 3-20 Per Capita GPP in the vicinities of Bangkok 1986-1996.

Pathum Thani province has income from taxation and high capital cost circulation. In 1996 it has 2,360 million baht of taxation and increased to 2,465 million baht or about 99 million baht (4.19%) in 1997. The capital cost circulation of commercial bank in 1997 is 94,363 million baht. In part of the outcome it is 4,290 and 5,314 million baht in 1996 and 1997 respectively.

Table 3-9 Incomes and expenditures of Pathum Thani local administration in 1997.

Municipal	Income (million baht)	Expenditure (million baht)	Spare
1. Muang	144	137	+7
2. Kukod	182	140	+42
3. Taklong	96	75	+21
4. Prachatipat	125	101	+24
5. Khlong Luang	56	21	+35
6. Lumlukka	12	11	+1
7. Sananrak	15	13	+2
8. Lumsai	7	5	+2
9. Bangtei	11	10	+1
10. Thanyaburi	28	24	+4
11. Nuangsua	11	-	+11
12. Bangsua	6	5	+1
13. Rahange	12	12	0
Total	**705**	**554**	**151**

Modified after: Office of Pathum Thani Provincial (1999)

3.12 Solid Wastes

3.12.1 Solid Wastes Management in Pathum Thani

The authority responsible for the solid waste management in Pathum Thani is a number of municipalities. There are totally 13 municipalities and many local administration bodies. The present situation of solid waste management is as follows:

Table 3-10 Solid waste generation in Pathum Thani

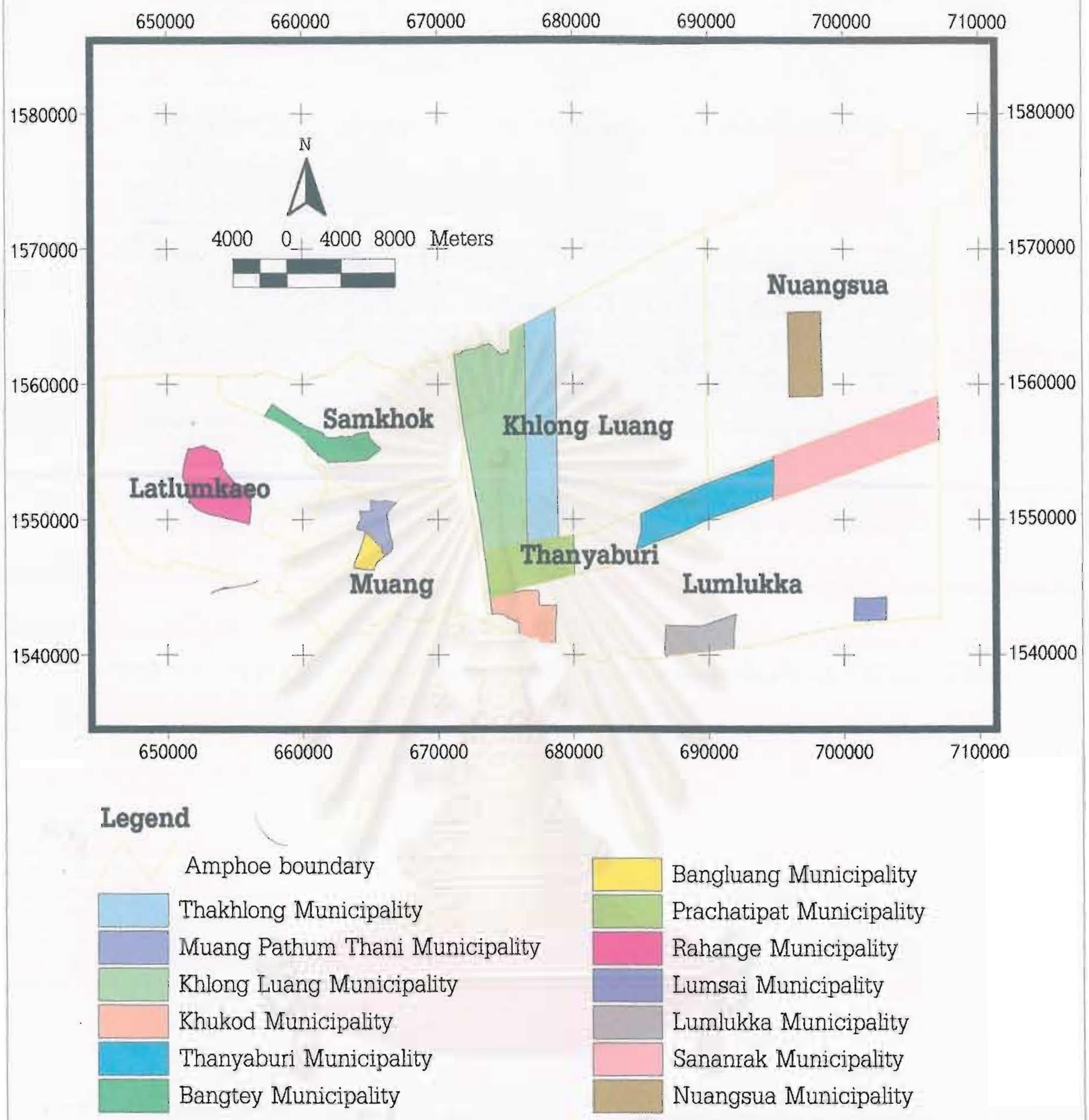
Municipality	Solid waste (ton/day)*
Muang Khukod**	70
Muang Pathum Thani**	24
Tambon Bangluang	6
Tambon Bangtey	3
Tambon Klongluang	100
Tambon Lumsai	10
Tambon Lumlukka	20
Tambon Nuangsua	10
Tambon Prachatipat	150
Tambon Rahang	3
Tambon Sananrak	20
Tambon Tanyaburi	30
Tambon Thakhlong	60
Organization of Tambon Administration	204
Total	**710**

* estimation

** population higher than 3,000 person/sq.km.

Source: each municipality in Pathum Thani,1999.

Although the "Muang" municipality with the population density more than "Tambon" municipality, but produces less solid wastes. This is because of the generation rate does not only depend on the number of population but also on the socio-economic and life style of people.



Modified after: Environmental Quality Promotion Department (1995)

SELECTION OF POTENTIAL SOLID WASTE DISPOSAL AREAS

IN PATHUM THANI PROVINCE

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Figure 3-21 The 13 Municipal areas of Pathum Thani province.

Figure 3-22 Existing solid waste disposal site on the west bank of Pathum Thani

Figure 3-23 Buildings in disposal site on the west bank of Pathum Thani

Figure 3-24 Road inside disposal site on the west bank of Pathum Thani

Figure 3-25 The complete landfill area in disposal site on the west bank of Pathum Thani

Figure 3-26 Existing solid waste disposal site on the east bank of Pathum Thani

Figure 3-27 The working truck on disposal site on the east bank of Pathum Thani

Figure 3-28 Built-up areas near disposal site on the east bank of Pathum Thani

Figure 3-29 Remain areas for landfill in disposal site on the east bank of Pathum Thani

3.12.2 Solid Wastes Generation and Projection

The existing solid waste quantity of the study area is 710 tons/day. Solid wastes generated in the municipal area of about 76% that can be handle each day by 66 trucks. This makes many residual wastes. The changing of generation rate of solid wastes relate to the socio-economic condition and standard of living, the habits and customs of living, season of the year, source reduction, public attitude, population, etc.(Yang,1994) will be rapidly increasing in the future. The critical problems are lack of solid waste disposal site, equipment and instrument for handling of waste, and technology to dispose.

In this study, the projection of solid wastes generation are assume by number of population because of there is a main relationship between number of population and quantity of solid waste. The value of correlation (r) between number of population and quantity of solid waste is 0.969245. This result points to confident value for assume the number of population and the generation rate of solid waste in the next decade (2009).

The number of population from Department of Provincial Administration and quantity of solid waste in 1993, 1995, 1997 and 1999 from Asdecon (1995), and Toraksa, (1995) apply to used as basic data in future forecast. In this study defined some variable for calculation as follows; concealed-population as 20% of whole population, percent of pick up wastes as 76%, and bulk density of solid waste as 0.2 tons/cb.m.

The generation rate of solid waste in year 1993, 1995, 1997 and 1999 are calculated from whole quantity of solid waste in one day divided by all of population. The equation is:

$$\text{Generation rate of solid waste} = \frac{\text{Quantity of solid waste in one day}}{\text{\% of pickup wastes} * (\text{register-population} + \text{concealed-population})}$$

$$\text{Generation rate (kg./person * day)} = \frac{\text{Quantity of solid waste in one day (tons)} * 1000}{0.76 * (\text{register-population} * 1.2)}$$

Then the population numbers and the generation rate of solid wastes from year 1993 to 1999 used to assume the number of them in the future. The Exponential Regression Analysis is applied to forecast the number of population and the generation rate of solid waste during the years 2001-2009. This method is selected because the value of correlation is close to 1 better than coefficients of correlation from the Linear Regression, Power Regression and Log Regression Analysis. The values of correlation (r) between the population and time, and between the generation rate of solid waste and time are 0.978674 and 0.94603246, respectively. The equations of exponential-regression is as follows:

$$Y = ae^{bx}$$

a, b, e = constant value from raw data analysis

x = independent variable

Y = dependent variable

Population equation:

$$Y = 461105.064 * e^{0.07505864x}$$

By Y = Number of population

x = Number of year (n)

Generation rate equation:

$$Y = 0.86656038 * e^{0.0863085x}$$

By Y = Generation rate

x = Number of year (n)

In the year 2009, the population number is close to 1 million and the cumulative weight of solid waste is 2,778,779 tons. The forecasting numbers are presented in Table 3.11.

Table 3-11 Projections of population and solid waste generation.

Number of year (n)	Year	Population (person)	Quantity of solid waste (tons/day)	Generation rate (kg./person/day)	Weight of solid waste (tons/year)	Cumulatiive weight (tons)	Volume of solid waste (cb.m./year)	Cumulatiive volume (cb.m.)
1	1993	500,086	446	0.977901976				
2	1995	524,251	474	0.991389319				
3	1997	592,328	590	1.092181738				
4	1999	616,636	710	1.262509441				
5	2001	671,100	1,074	1.334182854	392,172	392,172	1,960,861	1,960,861
6	2003	723,412	1,263	1.454449546	460,849	853,021	2,304,244	4,265,105
7	2005	779,799	1,484	1.585557389	541,550	1,394,571	2,707,751	6,972,856
8	2007	840,582	1,744	1.728483631	636,384	2,030,955	3,181,922	10,154,778
9	2009	906,103	2,048	1.884293615	747,825	2,778,779	3,739,127	13,893,895

The physical characteristics of solid wastes is among the wastes properly one of the factors for solid waste management apart from the solid waste quantity. The representative physical characteristics of solid wastes in the study area are as follows :

Table 3-12 Solid waste characteristics of Pathum Thani municipalities.

Type	% by weight					
	Muang*	Lumlukka**	Thanyaburi**	Kukod**	Sananrak**	Average**
-food waste or garbage	49.60	47.35	47.01	38.42	37.23	43.92
-paper	4.50	16.34	13.97	37.83	20.50	18.62
-plastic	24.00	26.29	19.03	16.54	19.54	21.21
-rubber	2.00	0.14	0.24	2.43	0.80	1.12
-leather & cloth	7.40	1.23	0.36	0.09	0.1	1.73
-leaf or branch of tree	6.50	7.05	8.23	3.34	9.92	7.01
-glass	1.70	0.72	3.69	0.68	6.73	2.70
-metal	2.90	0.77	5.29	0.21	3.71	2.58
-stone or a fragment of ceramic	1.00	0.00	2.00	0.39	0.00	0.67
-others	0.40	0.11	0.19	0.08	1.45	0.44
Total	100	100	100	100	100	100

Source : *Toraksa (1995)

**Asdecon (1995)

These waste compositions can be grouped into three kinds of waste following the disposal method. First, the solid wastes which can be composted (food waste or garbage, leaf or branch of tree) of about 50.93% by weight. Second, the combustible solid wastes (paper, plastic, rubber, leather, and clothes) of about 42.68% by weight. Third, the non-combustible solid wastes (glass, metal, stone and fragment of ceramic, and others) of about 6.39% by weight.

If the solid waste management in Pathum Thani is properly managed, a certain kind of wastes will be recycled prior bringing to disposal site. Some of the wastes that can be recycled are the paper, the plastic, the glass, and the metal. So the percentage by weight of the solid wastes will be decreased. As a result, combustible solid waste remains only 2.85% by weight (42.68%-39.83%). In addition, the non-combustible solid waste remains only 1.11% by weight (6.39%-5.28%).

So wastes from the municipal will be reduced to 54.89% by weight (50.93+2.85+1.11) after recycling processes. This result is brought to asseses the generation rate of solid waste status in the Pathum Thani province and the forecast generation rate in the next decade. At present, all of Pathum Thani municipalities have the total solid waste of 710 tons per day and can be reduced to 390 tons per day after recycling processes. This can be divided into compost solid wastes of 362 tons per day, combustible solid wastes of 20 tons per day, and non-combustible solid wastes of 8 tons per day. On the other hand, the cumulative weight of solid waste in year 2009 is 2,778,779 tons can be divided to compost solid waste 1,415,232 tons, combustible solid waste 1,185,983 tons, and non-combustible solid waste 177,564 tons. The quantity of solid wastes after recycling process, composting process, and incineration process is 38,764 tons. The final volume of solid waste for sanitary landfill is 193,818 cubic meters. Therefore, the area for sanitary landfill is 0.0387 square kilometer after design 3 lifts or nearly 5 meters for the deep of sanitary landfill site. (Figure 3-30)

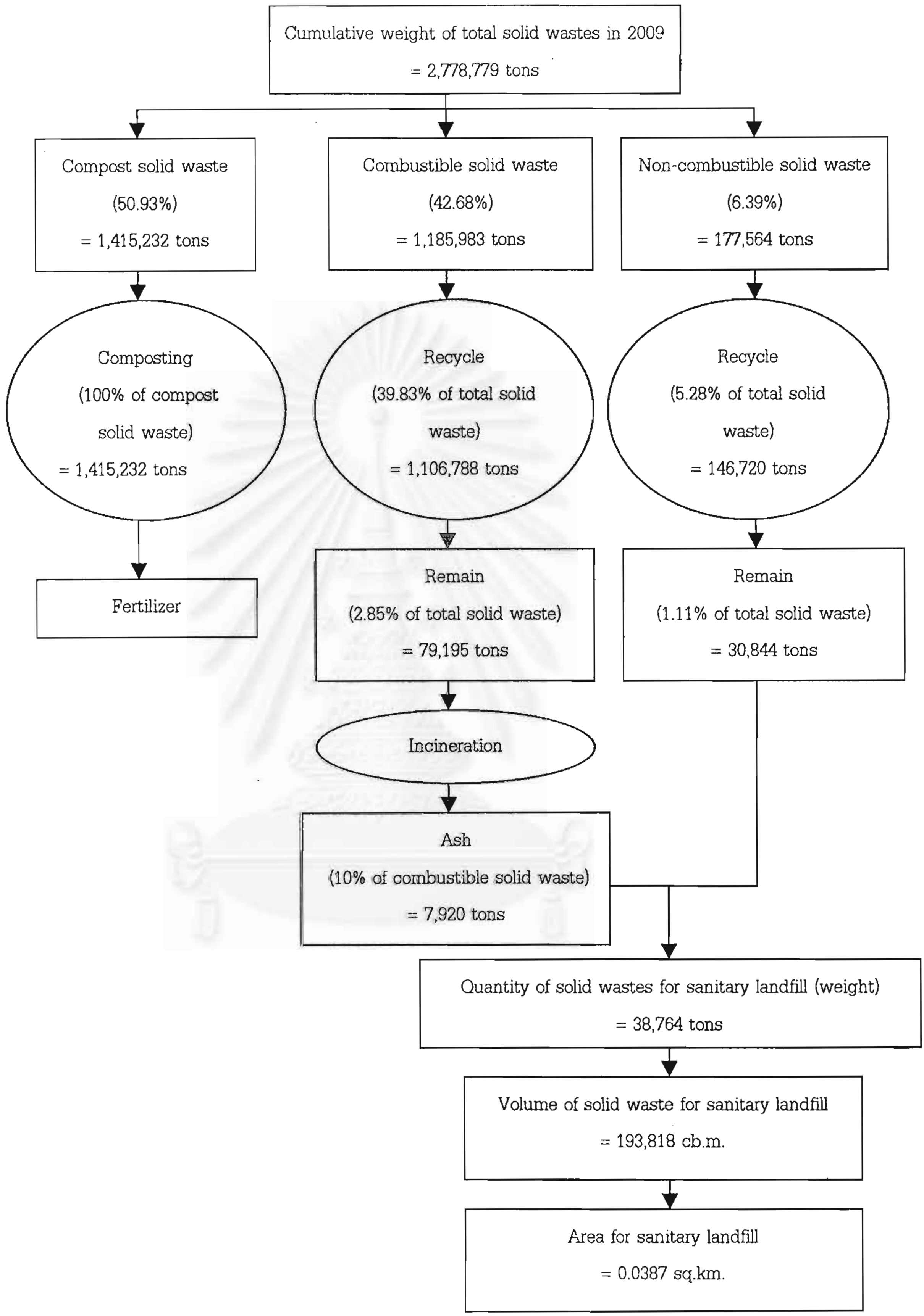

Figure 3-30 Flow chart of future solid waste management

CHAPTER 4

GIS DATA CAPTURE AND ANALYSIS

After forecast the quantity (weight and volume) of solid waste and the area for sanitary landfill in chapter 3, the next step is GIS application for area selection within environmental conditions. The application of GIS for selection of potential solid waste disposal area is considered to be most effective in establishing the linkage between all parameters concerned. Steps of work and method of study are as follows:

4.1 Data Collection

The existing data related to this study have been acquired in the forms of maps, digital map, reports, publications, and historical statistical records. They are as follows:

(a) Topographic map, on the scale of 1:50,000 with map sheet Nos. 5036I, 5037II, 5136I, 5136IV, 5137I, 5137II, and 5137III from the Royal Thai Survey Department, Bangkok, Thailand, 1992.

(b) Land use maps (Satellite imageries), on the scale of 1:15,000 from Thailand Remote Sensing Center, the National Research Council of Thailand, Bangkok 1988 and 1999.

(c) Soil map on the scale of 1:100,000 by the Soil Survey Division, Department of Land Development, 1972.

(d) Geological and Hydrogeological maps on scale 1:250,000 and 1:500,000 respectively from the Department of Mineral Resources.

(e) Map of water conservation area from the Pathum Thani Office.

(f) Meteorological observation records on Pathum Thani by the Don Muang Station; Meteorological Department.

(g) Population data from the department of Provincial Administration. and

(h) Some data in digital map form by the Department of Environmental Quality Promotion.

These data are served as basic input data for the Arc/Info program version 3.4 D and present as a series of maps by Arc/View program version 3.1.

4.2 Data Input

Spatial data and attribute data are transformed to the news database of different types.

4.2.1 Digitization

The digitizer is a tool for digitization of a map, tic points are defined to the reference points that allow all coverage features to be registered to a common co-ordinate system. The tic points for a map are selected according to study area. Under the present study, four tic points are selected at the four corners of the study area. UTM of four tic points are given in Table 4-1.

Table 4-1 UTM co-ordinate of Tic Points under the present study.

Tic Point	X Coordinate	Y Coordinate
1	715000	1585000
2	715000	1535000
3	640000	1535000
4	640000	1565000

The digitization of the tic points is very important before starting the digitization of a map. Because when digitizing or editing a coverage, tics are used to automatically transform digitizer coordinates into coverage coordinates. The Root Mean

Square (RMS) error is kept less than 0.003, the maximum permissible limit for digitization. The ADS command of Arc/Info is then used to digitize the maps.

Upon the digitization of the coverage, the line is used in the creation of the river and road coverage, and the polygon is used in the creation of the land use, soil and boundary coverages. If coverage is too large,the digitization can be carried out by portions. Before starting to digitize the coverage again, tic points are entered each time with the same RMS error limit as accepted criteria during the digitization of tic points. By doing so, the map is oriented to the exact position. Different data layers having different RMS error results unwanted sliver polygons during the matching of the boundary of the same feature in overlay functions.

4.2.2 Identification & Correction of Digitization Error

After digitization of a coverage, the next step was to display the map and correction of the error occurred during the digitization. Majority, dangle error (dangling nodes) are found. They indicated that a polygon does not close properly (undershoot)) or an arcs has exceeded its intersection with another arc (overshoot).

The undershoot errors are removed by using the MOVE with an assignment of proper fuzzy tolerance and dangle length. The fuzzy tolerance is defined as the minimum distance that separates all arc coordinates in a coverage. During the use of MOVE command, 2 or more arc coordinates within the fuzzy tolerance of each other are snapped together. Dangle length is the minimum length allowed for dangling arcs. The overshoot errors are disappeared by the use of DELETE command by selecting an arc that exceeded when its distance is less than fuzzy tolerance. Or else, the overshoot are corrected by select the arc and use SPLIT command and DELETE the arc that want to delete and then use MOVE command again.

4.2.3 Building Line/Polygon Topology

The next step after correction of errors is the creation of administration boundary, municipality boundary, land use, soil series, geology, surface water, ground water, precipitation level, and transportation coverage using BUILD command. In order to ensure that the arcs are stored as an order series of X, Y coordinate which defined a line, all arcs in coverage are sequentially numbered, the polygon is created by a number of arc which comprise its border. Similarly the arc topology is created for the streams and contour coverage in order to ensure that all arcs in a map are sequentially numbered, all arcs have directions.

4.2.4 Modifying Items

After obtaining the age cover that are built and cleaned already, the next step is to set the value for each polygon or line. Value of data that can put are numbers, characters and strings. They are assigned for the item name required. This item name can process and/or show within the function of Arc/Info and Arc/View. So, adding attribute data can be done in this step.

4.2.5 Appending

When the map is of very large size, APPEND command is used for bringing every maps that have joint border together. In this study, 7 map sheets following the topography map of Royal Thai Survey Department are being used.

4.3 Data Management

4.3.1 Buffer Zone

This is a function to generate the area outbound from point, line, or polygon along the distance. In this study, buffer distances of 60 m., 500 m., 700 m., 5 km., and 15 km. have been created for river, road, water well, built-up area, and municipal coverage, respectively.

4.3.2 Reclassification

After the data inventory, they are grouped and selected according to the objectives of the study and finally transform into new derivative maps. The classification of new data are presented in table 4-2.

Table 4-2 The classification of features for each database to be used in the GIS.

COVERAGE	FEATURE		
	POINT	LINE	POLYGON
1.SURFACE WATER		●	
2.ISOHYETAL			●
3.WATER CONSERVATION AREA			●
4.GROUNDWATER WELL	●		
5.GROUNDWATER			●
6.ROAD		●	
7.SOIL			●
8.GEOLOGY			●
9.LAND USE			●
10.AMPHOE			●
11.TAMBON			●
12.MUNICIPALITY			●
13.POPULATION			●

4.4 Settlement Level of Suitability

The importance for potential solid waste disposal site, as expressed in number, must consider the geology (including soil and groundwater) for the first priority, land use, precipitation, and surface water are the second priority, transportation as well as the municipal area in the decreasing are the third priority. Therefore, the importance are 3, 2, and 1, respectively.(Table 4-3)

The suitability number is assigned to be ranked from 8 (most suitable) to 0 (unsuitable) (see Table 4.4). The ranking is determined after applying many exclusionary criteria. The criteria cover land requirement, topographic condition, bed rock, soil characteristics, transportation location, hydrology, and surface water. (see Chapter 2). After the suitability number; S, and weight; W, are assigned for each category, the ranking score; C, is computed using the following equation.

$$C = \sum W_i S_i$$

Table 4-3 Importance number of each criteria.

Criteria or factors	Importance number (W)
1. Soil suitability	**3**
2. Hydrogeology	**3**
3. Land use	**2**
4. Road buffer	**1**
5. Surface water buffer	**3**
6. Isohyetal	**2**
7. Groundwater wells	**3**
8. Water conservation area	**3**
9. Municipal area	**1**
10.Geology	**3**

Table 4-4 Suitability number of each sub-criteria

Criteria	Sub-criteria	Rating (S)				
		0	2	4	6	8
1.Soil suitability	-Clay throughout				♠	
	-Clay or silty clay throughout				♠	
	-Clay or silty clay/silty clay loam over clay					♠
	-Sandy clay, clay loam or clay over loam or sandy clay loam over clay below 150 cm.					♠
	-Undifferentiated ridged acid sails	♠				
2.Hydrogeology	-Extensive and productive aquifers	♠				
	-Extensive but less productive aquifers					♠
3.Land use	-Agricultural land			♠		
	-Built-up area	♠				
	-Water body	♠				
	-Barren land					♠
4.Road buffer	-Road $\leq$ 500 m.	♠				
	-Road $>$ 500 m.					♠
5.Surface water buffer	-Surface water buffer $\leq$ 60 m.	♠				
	-Surface water buffer $>$ 60 m.					♠
6.Isohyetal	- 0-50 mm.					♠
	- 51-60 mm.				♠	
	- 61-70 mm.			♠		
	- 71-80 mm.		♠			
	- $>$ 80 mm.	♠				
7.Groundwater wells	-buffer $\leq$ 700 m.	♠				
	-buffer $>$ 700 m.					♠
8.Water conservation area	- inside	♠				
	- outside					♠
9.Municipal area	-buffer $\leq$ 15 km.					♠
	-buffer $>$ 15 km.	♠				
10.Geology	-Alluvial			♠		

Due to the criteria for the site selection of the sanitary landfill in chapter 2, the rating numbers (S) in table4-4 are set and defined numbers by priority importance. Firstly, the Environmental Quality Standard Division defined (1) the distance from municipality to the site should less than 15 kilometers, (2) The distance from community (built-up area) to the site should more than 5 kilometers to avoid the nuisance of odor, vapor and dust to man's health, and (3) the distance from main roads to the site should be farther than 300 meters. Secondly, the Pollution Control Department defined (1) distance from exist groundwater wells to the site should more than 700 meters, and (2) the most suitable should underlain with a great bed to support the weight of wastes. Thirdly, La Grega, Buckingham and Evans (1994) assigned soil suitability for landfill should be clay. Finally, Sukthawon (1996) recommended the distance from river to disposal site should be 60 meters. Therefore, the rating number (S) is set as 0, 2, 4, 6, and 8 for level of important from less important to most important respectively.

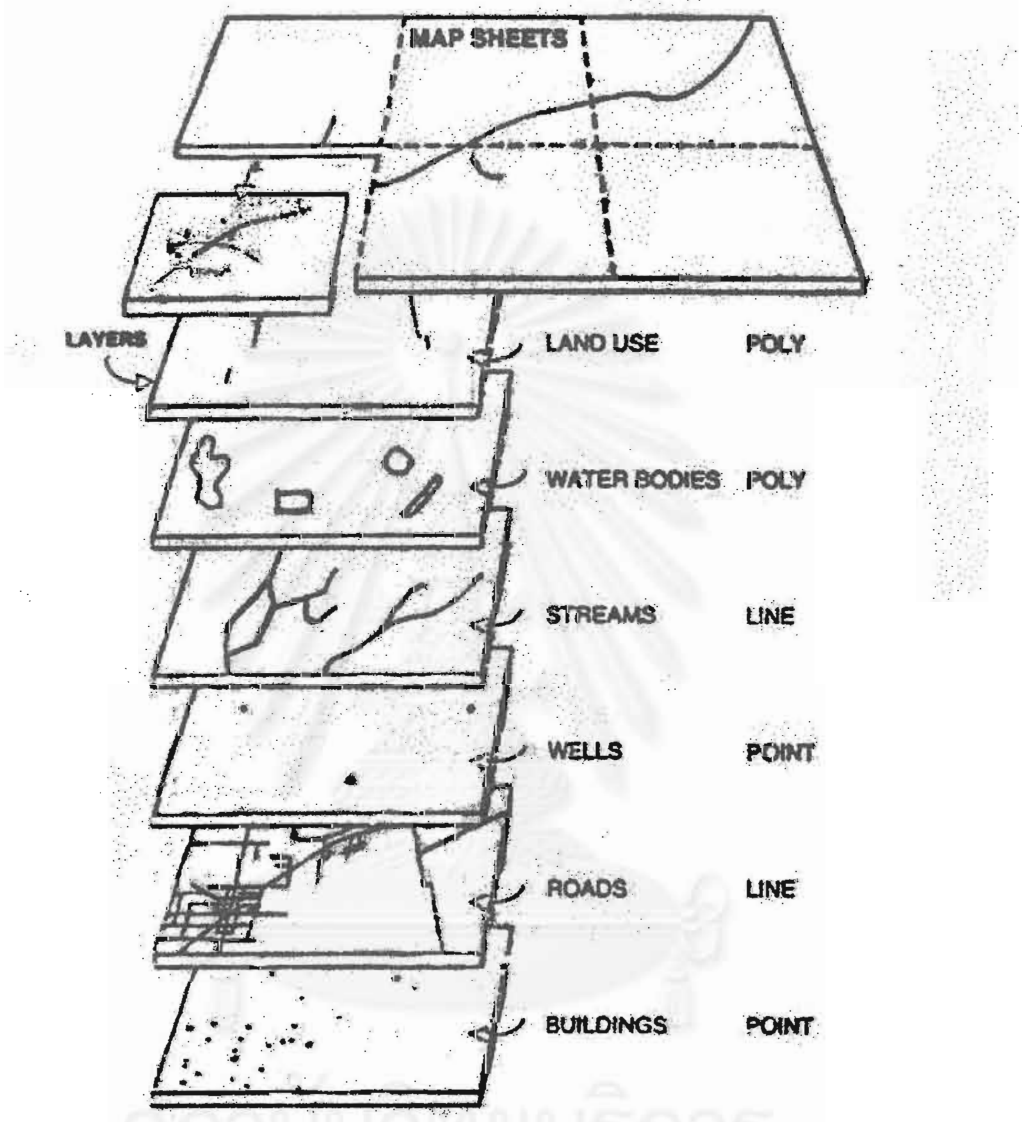

Figure 4-1 The overlay technique in GIS.

4.5 Database Analysis

The overlay technique and network are used for the analyses of database. The Arc/View program is used as a tool for information output for identifying potential site selection. The total score(C) of weight-rating is classified into 5 suitablility level. They are most suitable, suitable, moderately suitable, less suitable and unsuitable area. The score ranges of 0-24, 25-49, 50-74, 75-99, and 100-124 represent different degree of suitablity of unsuitable, less suitable, moderately suitable, suitable, and most suitable respectively.

Every criteria has been brought into the overlay process. The overlay process consists of many work functions in the Arc/View as UNION, INTERSEC, IDENTITY, CLIP, UPDATE, ERASE, MERGE, and BUFFER. Using these functions, the total score can be obtained from the equation.

$$C = \sum W_i S_I$$

By C = Total score of whole criteria or factors

W = Importance number of each criteria (Weight)

S = Suitability number of each sub-criteria

The importance number and suitability number of each coverage are calculated within overlay technique. The thematic map is processed from positive area map and negative area map. The range of score increases follow the upper level of process. When it UNION with all of coverage map the total score are 0-124. In contrast, the score of negative area map are 0. Therefore, the range of score is 0-124. The model of overlay process present in figure 4-2.

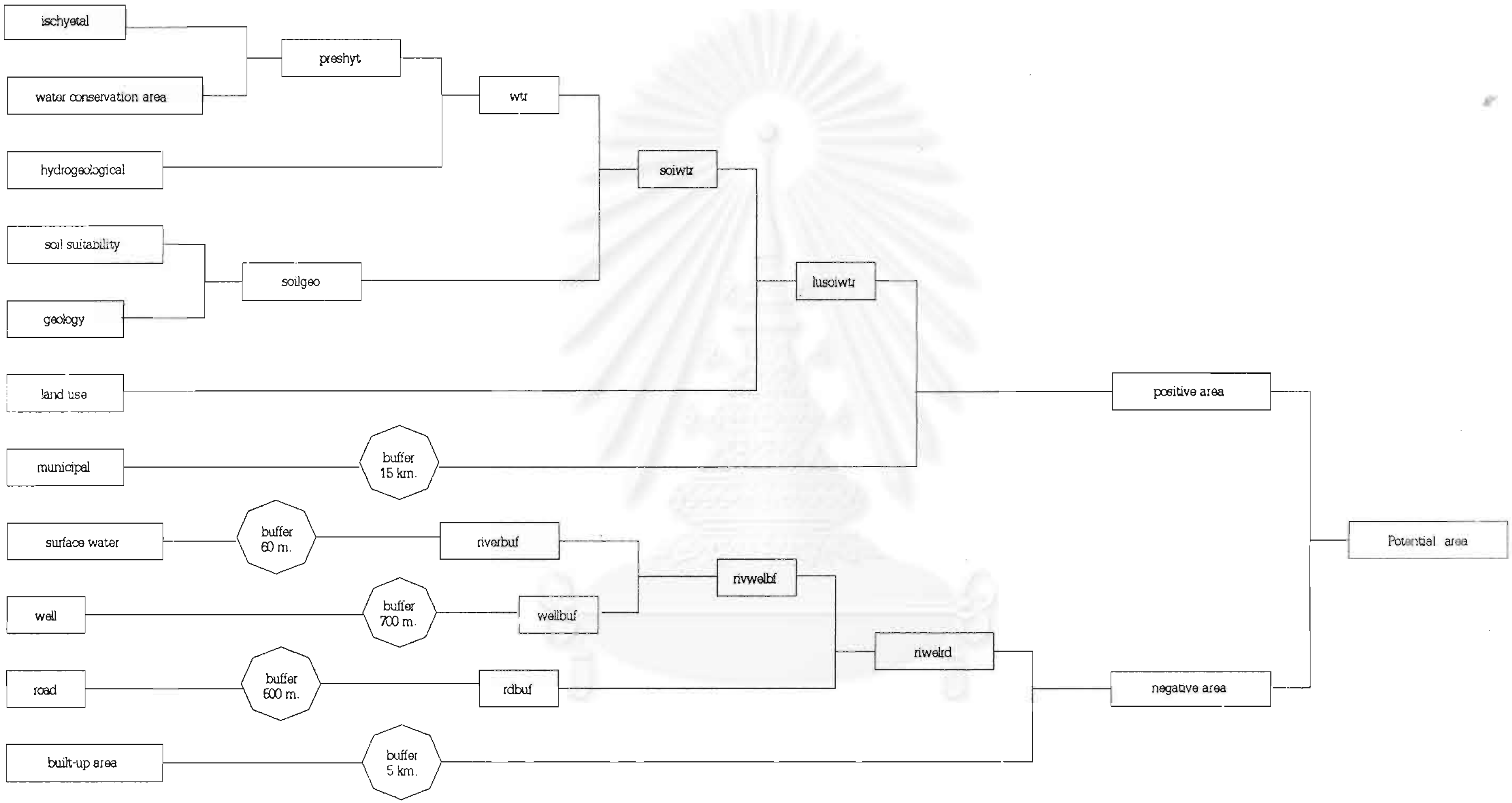

Figure 4-2 Analytical model of potential solid waste disposal area selection.

4.6 Field Study

A few field surveys are conducted on February, 1999 to March 2000. The purpose of the field surveys are to conduct the direct observation of various aspects, namely, land use, infrastructures, etc..

4.7 Economic consideration

After the potential solid waste disposal areas have been delineated with differrent degree of suitability. The land price of these areas to considered. The final decision will be reach after potential areas earlier selected have been evaluated in terms of land price.

4.8 Information Output

The information output will be the suitable areas for sanitary landfill and possibility for solid waste management plan in terms of both environmental and economy.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Primary Criteria Approach

In this study the criteria for the site selection of sanitary landfill are climate, surface water, groundwater, soil suitability, geology, landuse, transportation, and administration. These are categorized into positive and negative criteria. The map features or layers that considered to be the positive criteria are isohyetal, water conservation area, hydrogeological, soil, geological, landuse and municipal area maps. The negative criteria layers are river, water well, road, and built-up area.

5.2 Results From GIS Analysis

Outputs from the overlay technique under the weight rating system are categorized 5 classes of land suitability for the sanitary landfill.

The first class, "unsuitable area" is defined to cover the weight-rating score between 0 to 24. It is rarely found in the study area. The largest area in this class is 1.5 square kilometers is located in Amphoe Lumlukka.

The second class, "less suitable area", is defined to cover the weight-rating score between 25-49 marks. This class is located in Amphoe Sam Khok. Most of the areas are smaller than 0.25 square kilometers.

The third class, "moderately suitable area", is defined to cover the weight-rating score between 50-74. In this class, they are located in 4 Amphoes; namely, Lumlukka, Khlong Luang, Muang Pathum Thani, and Sam Khok, respectively in decreasing size of land. The large piece of moderately suitable areas are mostly located in Amphoe Lumlukka.

The fourth class, called "suitable area"; is defined within the score range of 75-100. These suitable areas for sanitary landfill are present in every amphoe, but are most abundant in Amphoe Nuangsua. Each area is usually large of about 5-10 square kilometers. The areas are less and less abundant in Amphoe Lumlukka, Amphoe Khlong Luang, and Amphoe Lat Lum Kaeo, respectively.

The last class, "most suitable area" is defined with the range of score from 100 to 124. These areas are in Amphoe Lumlukka, Amphoe Khlong Luang, and Amphoe Lat Lum Kaeo. In Amphoe Nuangsua, the area in this class occupies more than 50% of the total area. Each large area is about 5-7 square kilometers.

The area selected to be the potential areas for sanitary landfill with different degrees of suitability under the present study are summarized and presented in Figure 5-1.

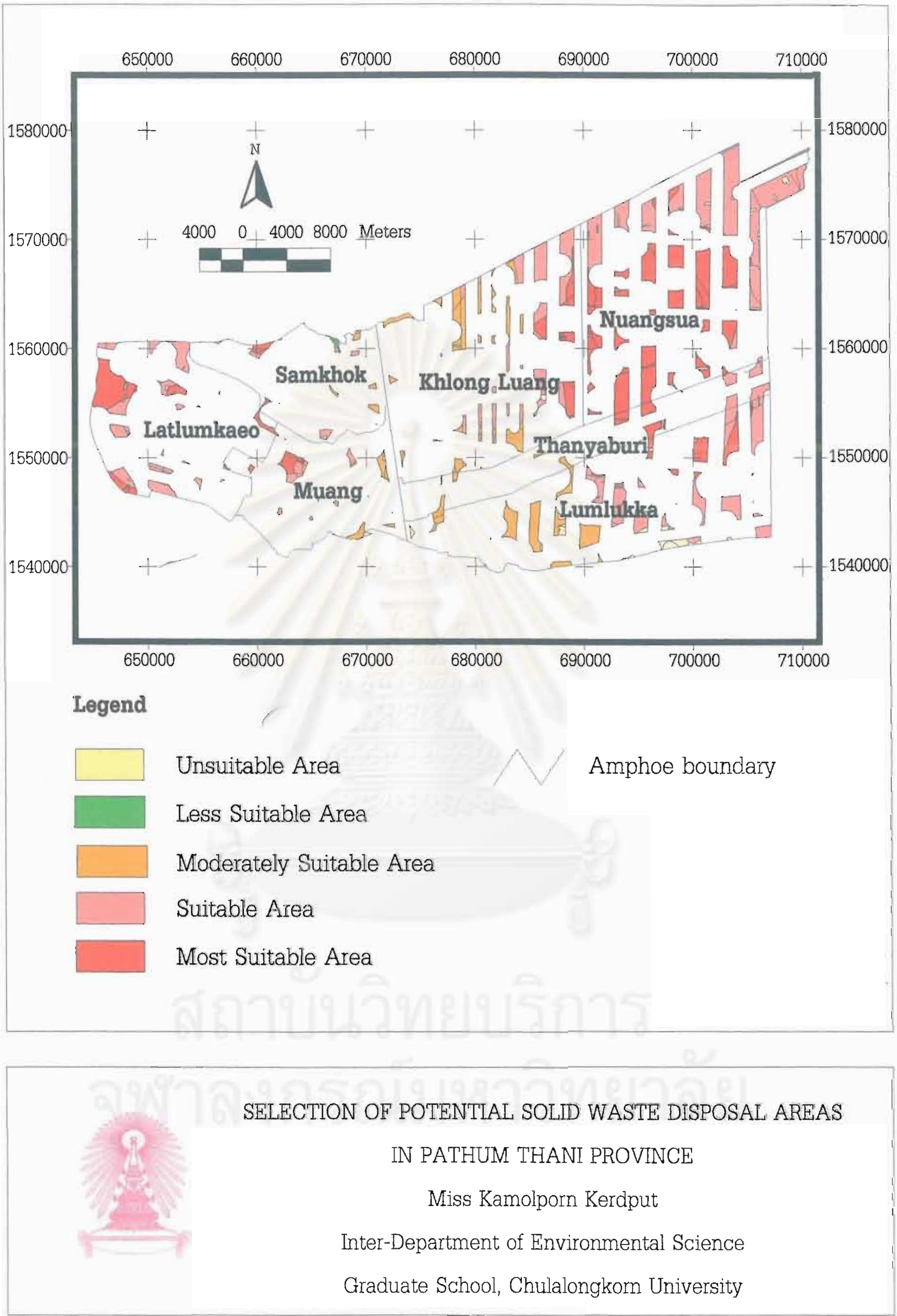

Figure 5-1 The 5 classes of potential solid waste disposal areas.

5.3 Secondary Criteria Approach

Population and quantity of solid waste in study area use Regression Analysis to forecast number of population, generation of solid waste and weight of solid waste in 2009. Then apply the TAMS-PIRNIE international co, ltd. Study for the Pathum Thani area. The output is volume of solid waste for sanitary landfill when use recycling, composting and incineration methods as primary criteria. (Figure 5-2) Due to the fact that the age of landfill site should be 5-10 years(Disathien, 1992), the projection of solid waste and population in chapter 3 used 10 year period on calculation.

The chart presents the area for sanitary landfill is 0.0387 square kilometer. Due to the fact that sanitary landfill site must have other operations as building, plants, roads, treatment ponds, equipment and vehicle shelters, etc., the adequate area for sanitary landfill site should be at least 1 square kilometer.

In this study, the socio-economic status of the selected areas are also considered. For the disposal site management, the knowledge on the land price of selected areas for future planning and management is critically important. So, the approximate prices of land in each amphoe for most suitable areas are taken into consideration for the possibility of potential solid waste disposal site.

The land price in Amphoe Nuangsua with more than 50% of most suitable areas are in range 500-6,000 baht per 4 square meters. The land price of most suitable area in Tambon Bungborn, Tambon Bungchumor, Tambon Bungkasam, Tambon Bungba, Tambon Nuangsamwang, and Tambon Noparat are 700-3,000, 600-4,000, 750-3,000, 1,000-6,000, 600-4,000, and 500-2,200 baht per 4 square meters, respectively.(Department of Land, 2000)

The results reveals the appropriate area in both of environmental conditions and socio-economic condition are in many part of Amphoe Nuangsua where are cheap land price. The capital cost of these area are in range 125-250 million bahts.

5.4 Disscussions

Due to the fact that the generation of solid wastes in the next ten years periods (1999-2009) will be increased from the present rate of 710 tons/day in 1999 to 2,048 tons/day in 2009. This output request area more than 2.77 square kilometers for cumulative volume of solid wastes 13,893,895 cubic meters but this study consider to recycling, composting, and incineration process that make the volume down to 193,818 cubic meters. Because of using primary treatment, the demand area for sanitary landfill is 0.0387 square kilometers. The sanitary landfill site must have 20-40% of the area for other operations. Therefore, 1 square kilometer enough for the sanitary landfill site. According to the suitable areas from the Arc/View and Arc/Info processes show that the areas are adequate for the potential sanitary landfill site next decades. The most suitable and suitable areas are almost in Amphoe Nuangsua where a relatively cheaper land price falls in the range of 500-1,000 baht per 4 square meters. Therefore, the capital cost of the land area of 1 square kilometer is approximately 125-250 millions baht.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

Based on the study on the potential areas for the sanitary landfill in the Pathum Thani province, the following conclusions and recommendations are reached.

6.1 Conclusions

Relationship between population growth and generation rate of solid waste are in the same trend. The present resettlement; built-up area in land use map in 1988 are almost scattered in Amphoe Muang, Khlongluang, and Lumlukka. When a decade passed (1999), there are more resettlement in Amphoe Muang, KhlongLuang, and Lumlukka.

The population growth has increased slowly up along the time scale upon the regression analysis, the correlation values (r) are 0.978672, 0.951638, 0.978674, and 0.95578046 for Linear, Log, Exponential and Power Regression respectively. Therefore, the number of population relates to the time scale under the exponential curve.

The generation rate of solid waste has growing up along the time scale upon the regression analysis, the correlation values (r) are 0.938452258, 0.85205862, 0.94603246, and 0.86323514 for Linear, Log, Exponential and Power Regression respectively. Therefore, the generation rate of solid waste relates to the time scale under the exponential curve. In addition, the number of population relates to the generation rate of solid waste.

Upon the application of the weight rating system on the area selection for sanitary landfill of Pathum Thani, the most suitable solid waste disposal areas are mainly located in Amphoes Nongsua, Lat Lum Kaeo, Lumlukka, Thanyaburi, Khlong Luang, and Muang Pathum Thani, respectively; in decrease order of importance. Furthermore, the suitable areas are found to be located in Amphoes Nongsua, Lumlukka, Lat Lum Kaeo, and Khlong Luang. Moreover, the moderately suitable areas are in Amphoes Khlong luang and Lumlukka. Finally, the less suitable and unsuitable areas are in Amphoe Lumlukka and Khlong luang. The potential solid waste disposal area is rarely found on Amphoes Muang, Sam Khok and the western part of Amphoe Khlong Luang because of abundant buffer areas for river and transportation routes.

Owing to the forecast generation of solid wastes in the next ten years (1999-2009) which will be double increases from the present rate in 1999, the area for sanitary landfill sites need at least 1 square kilometer for trench method with 5 meters depth.

In this study, the design of this sanitary landfill should consider the containment, control and management of leachate and gas from the site. In the lowest lift of the site, Geotextile or HDPE will be used for protecting the leachate contamination. Besides, the water treatment section for leachate treatment must be built on site. It is also necessary to install the methane gas detector on site for safety purpose.

6.2 Recommendations

The land use map as interpreted from the Landsat TM imageries shows some differences when compared with the information obtained from the the Land Development Department. This is due to the fact that tones of the photographs of the same area are not similar although there is no change in landuse pattern. Besides, it is partly due to limited experience in the interpretation of satellite imageries under the present study. In order to obtain the better information output, it is recommended the PCI program should be used.

It is noted that almost all data and information obtained from different government agencies are not of compatible quality and consistency. Therefore, a certain degree of adjustment is necessary required. Besides, the references of ground positioning of different satellite-based system and the ground-surveying system are different and require some degree of calibration. Therefore, the full understanding of this matter is critical.

The flood risk factor; an important factor, has not been considered in this study area due to the limitation of study and data. Therefore, the future study should assess on this factor too.

The factors that are used in this study area should be use more factor in the future study or in the new other study area. Because of the landform of Pathum Thani province is almost homogeneous. Therefore, the study has less factors to classified each criteria.

Besides, the applications of GIS should have update database for getting the close and accurate information output.

Possibility to use this study as an action should be set a rule for responsibility on solid waste management. The "Polluter Pay Principle" is an important practice to improve the habit of polluter. The strategy may be set regulations up for instance; the polluter should pay the money for the pick up waste follow the weight or volume of waste, and should spent the money for waste management follow the number of people in the house. It will reduce the generation rate or quantity of solid waste and change the characteristics of solid wastes.

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