CHAPTER 4

THE ANALYTICAL RESULTS OF POTENTIAL AREA FOR SANITARY LANDFILL

4.1 Land Requirement for Sanitary Landfill Calculation

In this part, the calculations for sanitary landfill are divided into two steps, which include the quantities of solid waste calculation (for 20 years) and area calculation (lifespan at least 20 yrs). The details of calculation are described as follows:

4.1.1 The Quantities of Solid Waste Calculation

There are three parameters the quantities of solid waste calculation that include number of population in next 20 years, the solid waste generated rate, and the physical characteristic of solid waste.

- Number of Population During 1994-2013

Field and Mac Gregor (1992) proposed several forecasting techniques for population prediction. However, in the present study uses geometric/exponential trend for determining the growth rate. Generally, the formula for geometric growth is expressed as:

$$P_{(t+n)} = (1+r)^n \times P_{(t)} \qquad (4.1)$$

where $P_{(t)}$ is the population at time t – the base year (person),

$P_{(t+n)}$ is the population to be forecast at time t+n (person),

n is the number of years between t and t+n (year),

r is the annual growth rate.

From equation (4.1), $P_{(t)}$ and $P_{(t+n)}$ are replaced by number of population of each municipal/sanitary in Changwat Chachoengsao during 1983 to 1992 and 1984 to 1993, year by year, respectively. As a result, growth rate (r_i) of each year of each municipal/sanitary are presented in Appendix A-Table A.1. From Table A.1, mean growth rate *(r)* in Changwat Chachoengsao during 1983 to 1993 ranges from 0.000210 to 0.089117. However, it is significant to note here that the boundary of Tha Kham sanitary, Hua Samrong sanitary, Thung Sa Dao sanitary, Saladaeng sanitary, Khao Hinson sanitary, and Ratchasan sanitary are separated from Bang Pakong sanitary, Plaeng Yao sanitary, Don Chim Plee sanitary, Phanom Sarakham sanitary, respectively. Consequently, growth rate of these sanitaries are calculated from their mother sanitary.

The mean growth rate of each municipal/sanitary is used for predicting number of population during 1994-2013. Therefore, total number of population is about 3,614,629 persons. More details are presented in Appendix A-Table A.2

- The Solid Waste Generate Rate

Loawatcharin (1988) who referred to JICA (1982) studied that the relationship between the GDP of province and the solid waste generated rate in Bangkok Metropolis. As a result, if the GDP is increased 10%, the increasing solid waste generated rate is computed as 3.3%.

According to Modus Consultant Co., Ltd. (in thai, 1995), solid waste generated rate of Bangkok Metropolis and Changwat Chachoengsao are 0.88 kg/capita/day and 0.65 kg/capita/day, respectively. The growth economic of Changwat Chachoengsao in next 20 years should be less than or equal to the growth economic of Bangkok. Should be large enough to accommodate solid waste for life of solid waste production, in the present study use 0.88 kg/capita/day of solid waste generated rate for the quantities of solid waste calculation in Changwat Chachoengsao. Consequently, the formula for calculation of the quantities of solid waste in a year are expressed as:

$$Q_w = P \times Rw \qquad (4.2)$$

where Q_w is the quantities of solid waste time $t+n$ (kg),

P is the population to be forecast at time $t+n$ (person),

Rw is the solid waste generated rate (kg/capita/day).

From equation (4.2), P and Rw are replaced by 3,614,629 persons of total number of population in Changwat Chachoengsao during 1994 to 2013, and 0.88 kg/capita/day of the solid waste generated rate. Consequently, the quantities of solid waste in Changwat Chachoengsao are 1,161,819,003 kg. The quantities of solid waste of each municipal/sanitary in Changwat Chachoengsao are presented in Appendix A-Table A.3

- The Physical Characteristic of Solid Waste in Changwat Chachoengsao

The physical characteristics of solid waste in Changwat Chachoengsao are summarized in Appendix A-Table A.4. Compositions of solid waste are grouped into three types of solid waste following the disposal method (Kerdput, 1998) including composted solid waste type (food waste or garbage, and leaf or branch of tree), combustible solid waste type (paper, plastic, rubber, leather, and clothes), and non-combustible solid waste type (glass, metal, stone, fragment of ceramic, and others) which percentage by weight as 49.35%, 39.23%, and 11.42%, respectively.

If solid waste management in Changwat Chachoengsao is properly managed, a certain kind of solid waste will be recycled prior bringing to disposal site. Some of solid waste can be recycled (e.g. paper, plastic, glass, and metal). Therefore, percentage by weight of solid waste will be decreased. As a result, combustible solid waste remains only 3.18% by weight (39.23%- 36.05%). in addition, the non-combustible solid waste remains only 3.46% by weight (11.42%-7.96%).

Thus, solid waste from the municipal will be reduced to 55.99% by weight (49.35+3.18+3.46) after recycling processes. The cumulative weight of solid waste during 1994-2013 is 1,161,819,003 kg (1,161,819 tons) can be divided into 3 categories including 573,357,678 kg (573,358 tons) of composted solid waste, 455,781,595 kg (455,782 tons) of combustible solid waste, and 132,679,730 kg

(132,680 tons) of non-combustible solid waste. The quantities of solid waste after recycling process are 650,502,460 kg (650,502 tons).

However, for large enough for sanitary landfill, total quantities of solid waste are used for land requirement calculation in next step. Table 4.1 shows the quantities of each type of solid waste that are produced in Changwat Chachoengsao.

4.1.2 Land Requirement Calculation

The total quantities of solid waste that are produced during 1994-2013 are conducted for land requirement calculation. There are many parameters for the land requirement calculation. However, six parameters are considered in this research, which include the quantities of solid waste, compacted density of solid waste, sanitary landfill design, volume of cover material, the required leachate treatment plant area, and miscellaneous area as described as follows:

- The Quantities of Solid Waste

The quantities of solid waste of Changwat Chachoengsao that were previously calculated in Chapter 4.1.1, are 1,161,819,003 kg.

- Compacted Density of Solid Waste in Sanitary landfill

Loawatcharin (1998) explained that compacted density of solid waste should be range between 530-710 kg/m^3. He also advised that 550 kg/m^3 of compacted of solid waste is suitable for sanitary landfill in Thailand. Thus, 550 kg/m^3 of compacted of solid waste is acceptable in the present study. Consequently, total volume of compacted solid waste is computed, and the result is 2,112,398 m^3. More details are presented in Appendix A-Table A.5.

Table 4.1 The Quantities of Each Type pf Solid Waste (SW) that are Produced in Changwat Chachoengsao.

Year	Number of Population (persons)	Rate of SW Generated (kg/capita/day)	Whole Quantities of SW (kg/day)	Whole Quantities of SW (kg/year)	Quantities of Each Type of SW			Quantities of SW After Recycle (55.99%)
					Compost (49.35%)	Combustible (39.23%)	Non-combustible (11.42%)	
1994	160.006	0.88	140.805	51.393.825	25.362.853	20.161.798	5.869.175	28.775.403
1995	161.830	0.88	142.410	51.979.650	25.651.957	20.391.617	5.936.076	29.103.406
1996	163.700	0.88	144.056	52.724.496	26.019.539	20.683.820	6.021.137	29.520.445
1997	165.620	0.88	145.746	53.197.290	26.252.863	20.869.297	6.075.131	29.785.163
1998	167.590	0.88	147.479	53.829.835	26.565.024	21.117.444	6.147.367	30.139.325
1999	169.615	0.88	149.261	54.480.265	26.886.011	21.372.608	6.221.646	30.503.500
2000	171.697	0.88	151.093	55.300.038	27.290.569	21.694.205	6.315.264	30.962.491
2001	173.840	0.88	152.979	55.837.335	27.555.725	21.904.986	6.376.624	31.263.324
2002	176.046	0.88	154.920	56.545.800	27.905.352	22.182.917	6.457.530	31.659.993
2003	178.320	0.88	156.922	57.276.530	28.265.967	22.469.583	6.540.980	32.069.129
2004	180.665	0.88	158.985	58.188.510	28.716.030	22.827.352	6.645.128	32.579.747
2005	183.086	0.88	161.116	58.807.340	29.021.422	23.070.119	6.715.798	32.926.230
2006	185.587	0.88	163.317	59.610.705	29.417.883	23.385.280	6.807.542	33.376.034
2007	188.173	0.88	165.592	60.441.080	29.827.673	23.711.036	6.902.371	33.840.961
2008	190.850	0.88	167.948	61.468.968	30.334.936	24.114.276	7.019.756	34.416.475
2009	193.623	0.88	170.388	62.191.620	30.691.564	24.397.773	7.102.283	34.821.088
2010	196.499	0.88	172.919	63.115.435	31.147.467	24.760.185	7.207.783	35.338.332
2011	199.484	0.88	175.546	64.074.290	31.620.662	25.136.344	7.317.284	35.875.195
2012	202.586	0.88	178.276	65.249.016	32.200.389	25.597.189	7.451.438	36.532.924
2013	205.812	0.88	181.115	66.106.975	32.623.792	25.933.766	7.549.417	37.013.295
Total			3.180.873	1.161.819.003*	573.357.678	455.781.595	132.679.730	650.502.460

Note. *: Use for Land requirement Calculation

- Volume of Cover

Noble (1976) explained that a sufficient amount of cover soil should be available to insure 1 part of cover soil for 4 parts of refuse in the completed landfill. In addition, daily and interim cover needs are expressed as a waste/soil ratio, defined as the volume of waste deposited per unit volume of cover provided. Typically, waste/soil ratios range from 4:1 to 10:1(Kreith, 1994). Thus, waste/soil ratio 4:1 is employed in the present study.

Volume of compacted solid waste is 2,112,398 m^3. Therefore, volume of cover material is 528,104 m^3. More details are presented in Appendix A-Table A.5.

- Sanitary landfill Design

From liners, slope stability, groundwater level, the conceptual model of sanitary landfill design is created (see Appendix A-Figure A.1). From Figure A.1, 3 lifts of compacted solid (2 lifts for area method, 1 lift for trench method), 2 meters of the height of each lift, 30° of side slope, liners (synthetic and clay liners), and geological barrier are proposed in the present study. From Section 2.2.3.4, Sanitary landfill Base Liners subject, when considered 2.5 m of base of compacted solid waste, 1 m of both liners, and 2.5 m of geological barrier, the depth of the groundwater level should be detected at least 6 m from ground surface. Consequently, groundwater level less than or equal 6 m from ground surface is one of negative criteria for sanitary landfill selection in the step of GIS analysis (see Table 4.4).

Net volume of compacted solid waste (including volume of cover material) is computed for area of compacted solid waste. As a result, area for compacted solid waste is 441,700 m^2. In Appendix A-Table A.6 shows calculation method for compacted solid waste area.

- The Required Leachate Treatment Plant Area

At each site, it should be prepared area for leachate treatment plant should be established. Loawatcharin (1998) mentioned that 20% of leachate is produced from the amount of rainfall. The formula of amount of rainfall determination on sanitary landfill is expressed as below.

$$Q_{rf} = Q_{rd} \times A_{w} \qquad (4.3)$$

where Q_{rf} = the amount of rainfall falling on a sanitary landfill m^3,

Q_{rd} = the amount of rainfall for a day m,

A_w = area of compacted solid waste m^2.

Generally, leachate is a result of the percolation of precipitation, uncontrolled runoff, and irrigation water into the sanitary landfill (Pfeffer, 1992). For the present study used percolation of precipitation into the sanitary landfill to calculate area for leachate treatment plant.

The maximum of mean monthly rainfall and average rain-day of Changwat Chachoengsao during 1967-1999 were measured at Station numbe 423009 (Phanom Sarakham Animal Breeding) that were 288.8 mm. of mean rainfall and 19.2 days of rain-day in September. Area for compacted solid waste, a maximum of mean monthly rainfall, and average rain-day are replaced in equation (4.3). Therefore, the amount of rainfall falling on a sanitary landfill is computed that is about 6,643 m^3.

Loawatcharin (1998) suggested that leachate treatment plant, including faculative pond, and stabilization pond. The former should be 2.00-3.00 m of depth and 10 day of detentional time while the latter should be 1.2-1.5 m of depth and 20 day of detentional time. The formula for faculative pond and stabilization pond calculation are expressed as follows:

Faculative pond:

$$A_{fp} = \frac{V_{fp}}{D_{fp}} \quad \text{...(4.4)}$$

where $V_{fp} = \left(Q_{rf} \times \frac{20}{100}\right) \times 10$

Q_{rf}	=	the amount of rainfall falling on a sanitary landfill	m^3,
V_{fp}	=	capacity or volume of faculative pond	m^3,
D_{fp}	=	depth of faculative pond	m, and
A_{fp}	=	area of faculative pond	m^2.

Stabilization pond:

$$A_{sp} = \frac{V_{sp}}{D_{sp}} \quad \text{...(4.5)}$$

where $V_{sp} = \left(Q_{rf} \times \frac{20}{100}\right) \times 20$

Q_{rf}	=	the amount of rainfall falling on a sanitary landfill	m^3,
V_{sp}	=	capacity or volume of stabilization pond	m^3,
D_{sp}	=	depth of stabilization pond	m, and
A_{sp}	=	area of stabilization pond	m^2.

The calculation will be done by replacing 6,643 m^3 of the amount of rainfall falling on a sanitary landfill, 2 m of depth of faculative pond, and 1.5 m of depth of stabilization pond in equations (4.4) and (4.5), respectively. As a result, area of faculative pond and area of stabilization pond are computed that are about 5,314 m^2, 17,715 m^2, respectively (see calculation method in Appendix-Table A.7).

- Miscellaneous Area

Loawatcharin (1998) suggested that the sanitary landfill area should be included miscellaneous area (i.e., internal road system, plant zone, drainage lane, equipment storage, house of laborer). In this research, there are 10 m of width for internal road system, 10 m of width for plant zone, 150 m^2 for equipment storage, and 100 m^2 for house of laborer. As a result, area for miscellaneous area is 60,750 m^2.

Plus Area for compacted municipal solid waste (Including daily cover), area for leachate treatment plant, and miscellaneous areas. As a result, total area is 525,479 m^2. For excess area for sanitary landfill, 20% of excess area is also computed. Consequently, total land requirement for sanitary landfill in Changwat Chachoengsao is calculated that is 630,575 m^2. They are summarized in Table 4.2

Table 4.2 Land Requirement for Sanitary Landfill in Changwat Chachoengsao

NO.	CATEGORIES	AREA SIZE (m^2)
1	Area for Compacted Municipal Solid Waste (Including daily cover)	441,700
2	Area for Leachate Treatment Plant 2.1 Faculative Pond	5,314
	2.2 Stabilization Pond	17,715
3	Miscellaneous areas (Including internal road system, plant zone, drainage lane, equipment storage, house of laborer)	60,750
	SUM	525,479
	20% excess area	105,096
	TOTOL	630.575

4.2 Preparation Database and Analysis Using GIS Technique

Two sub steps are designed in this part, including criteria identification, and preparation database and analysis using GIS technique.

4.2.1 Criteria Identification

There are two main criteria for selecting suitable areas for solid waste disposal (sanitary landfill) in both positive and negative prospective.

4.2.1.1 Positive Criteria

The suitable areas selection should be done positively and should taken two categories, including physical and geological conditions into consideration (see Table 4.3).

Table 4.3 Summary of Positive Criteria

No.	Category	Positive Criteria
1	Physical condition	1) Slope should be less than 20%. 2) Depth of soil should be $\geq$ 5 m (Van der wall) 3) Texture of soil — Upper soil should be well drained. — Lower soil should be low permeability. 4) No flood 5) Less or rarely possibility of flood prone area (terrain characteristic) 6) Groundwater table should be more than or equal 1.5 m from ground surface.
2	Geological conditions	1) High content of clay 2) Low permeability 3) Unfissured, no fracture, no sinkhole 4) Homogeneous

4.2.1.2 Negative Criteria

The negative criteria for the sanitary landfill selection are in general incompatible waste disposal site because of the existing landuse of the characteristic of areas. The sanitary landfill needs controlling and preventing environmental impacts in the long term. Table 4.4 shows the summaries of negative criteria, which are described as below.

Table 4.4 Summary of Negative Criteria

No.	Parameters	Negative Criteria
1	Area	Area of sanitary landfill site is less than 630,575 m^2. See in Table 4.2.
2	Slope	Slope is more than 20% (Disathien, 1992).
3.	Intensive and urban areas	Area that located less than 5 km from intensive and urban areas (Kerdput, 1999).
4.	Village	Area that located less than 500 m from village (Boonlue, 1998).
5.	Transportation	Area that located less than 300 m from main road (Kerdput, 1999).
6.	Historical and Archaeological areas	Area that located far from ancient remains boundary further less than 1 km (Pollution Control Department; PCD 1998).
7.	Industrial facilities	Area that located within Industrial facilities land (Boonlue, 1998).
8.	Watershed	Area that located within the watershed Class 1A, 1B, and Class 2 (PCD, 1998)
9.	Surface water resources	Area that located far from natural/man-made water resources including stream, wetland, and water body less than 300 m, excluding the water body used in the sanitary landfill site (PCD, 1998)

Table 4.4 Summary of Negative Criteria (continued)

No.	Parameters	Negative Criteria
10.	Groundwater well and water supply station	Area that located far from groundwater well and water supply station less than 700 m (PCD, 1998)
11.	Groundwater level	Groundwater level is found less than 6 m from ground surface (see in both Sanitary landfill Design subject and Appendix A-Figure A.1).
12.	Forest	Area that located within forest conservation type area (Boonlue, 1998).
13.	Mineral resources	Area that located within mineral resources (Boonlue, 1998).
14.	Geology Structure	Area that located far from active fault* less than (Boonlue, 1998).
15.	Expected well yield	Area that expected well yield is more than or equal 5 m^3
16.	Flood prone area	Area that is very high or high possibility of flood prone area.

Note. Fault*: According to (Boonlue, 1998), sanitary landfill should be located far from active fault at least 500 m, but fault structure within the study area no have data. Therefore, whole fault structures in the study are buffered.

4.2.2 GIS Analysis

There are two main step of GIS analysis, including positive mapping and negative mapping. Both of them are analyzed, and then, suitable areas are selected. The detailed results are described as below.

4.2.2.1 Positive Mapping

In the present study, it was considered to be too expensive to conduct field investigations, especially drilling and permeability tests to get specific information on the lithology and permeability of the whole area. Soil map, geological map, and groundwater map are employed in this step. Because of the lack of detailed information, the general information from the soil map of Changwat Chachoengsao at scale 1:50000 (Figure 3.23), the geologic map at scale 1:250000 (Figure 3.10), and the groundwater map at scale 1:100000 (groundwater aquifer map, Figure 3.15) are used for assessment of the suitable areas. The assessment of each map is described as a follow:

- The Suitable Physical Conditions Derived from Soil Map

The suitable physical conditions for sanitary landfill site should have some considerations, which include less than 20% of slope, $\geq$ 5 m of soil depth, well drainage of upper soil, low permeability of lower soil, no flood, and less or rarely possibility of flood prone area (terrain characteristic) (see Table 4.3). They are classified into three classes, namely, suitable, fair, and non-suitable. Figure 4.1 shows suitable physical condition, which is derived from the soil map. For Table 4.5 summarizes theirs suitable areas while are based on the existing soil map, geological map, and groundwater map.

- The Suitable Areas Derived from Geological Map & Groundwater Map

The criteria in considering the suitable geological conditions for sanitary landfill site should have some consideration, which include high content of clay in weathered rocks (fine grains), low permeability, no fracture/no sinkhole areas, and homogeneous characteristics. They are classified into three classes, namely, suitable, fair, and non-suitable (see Table 4.5). Figured 4.2 and 4.3 show suitable geological condition, which are derived from the geological map and groundwater map, respectively.

Consequently, suitable and fair physical and geological conditions are integrated and compiled to be the positive map as illustrated in Figure 4.4. The map can be subdivided into two classes, namely, suitable and non-suitable.

For the physical and geological conditions evaluations, they can be categorized in Appendix B-Table B.1-B.4.

Table 4.5 Summary of Suitable Area Classification.

Data	**Category**			**Remark**
	Suitable	**Fair**	**Non-suitable**	
Soil Map	35, 35B 35/17, 41B	35C, 40, 40B, 40B/46B, 40C, 46/25	2, 2/11, 2/3, 8, 10, 11, 12, 13, 3, 16, 16/6, 17, 17/6, 17B, 18, 24, 25, 25/49, 25B/17B, 35B/43B, 43B, 43, 43/24, 46/48, 46/56, 46, 46B, 46C, 47B, 47B/55, 47C, 47C/55C, 48, 48B, 48C, 48D, 48E, 51B/53B, 51C/53C, 55, 56, 56B, 56B/48B, 56C/48C, 59, 60, 62, 62/47E, 62/48C	Physical Condition
Geological Map	Ck1, Ck2, Post C, Post Pv		PEsch, SD, CP, P	Geological Condition
Groundwater Map	Rv	Rss	Rgr, Rsch	

Note: 35, 40B, and 51B/53B = Soil units (see Table 3.9)

Ck1, Ck2, Post C, Post Pv, PEsch, SD, CP, P = Rock units (see Figure 3.10)

Rv, Rss, Rgr, and Rsch = Groundwater aquifers (see Figure 3.15)

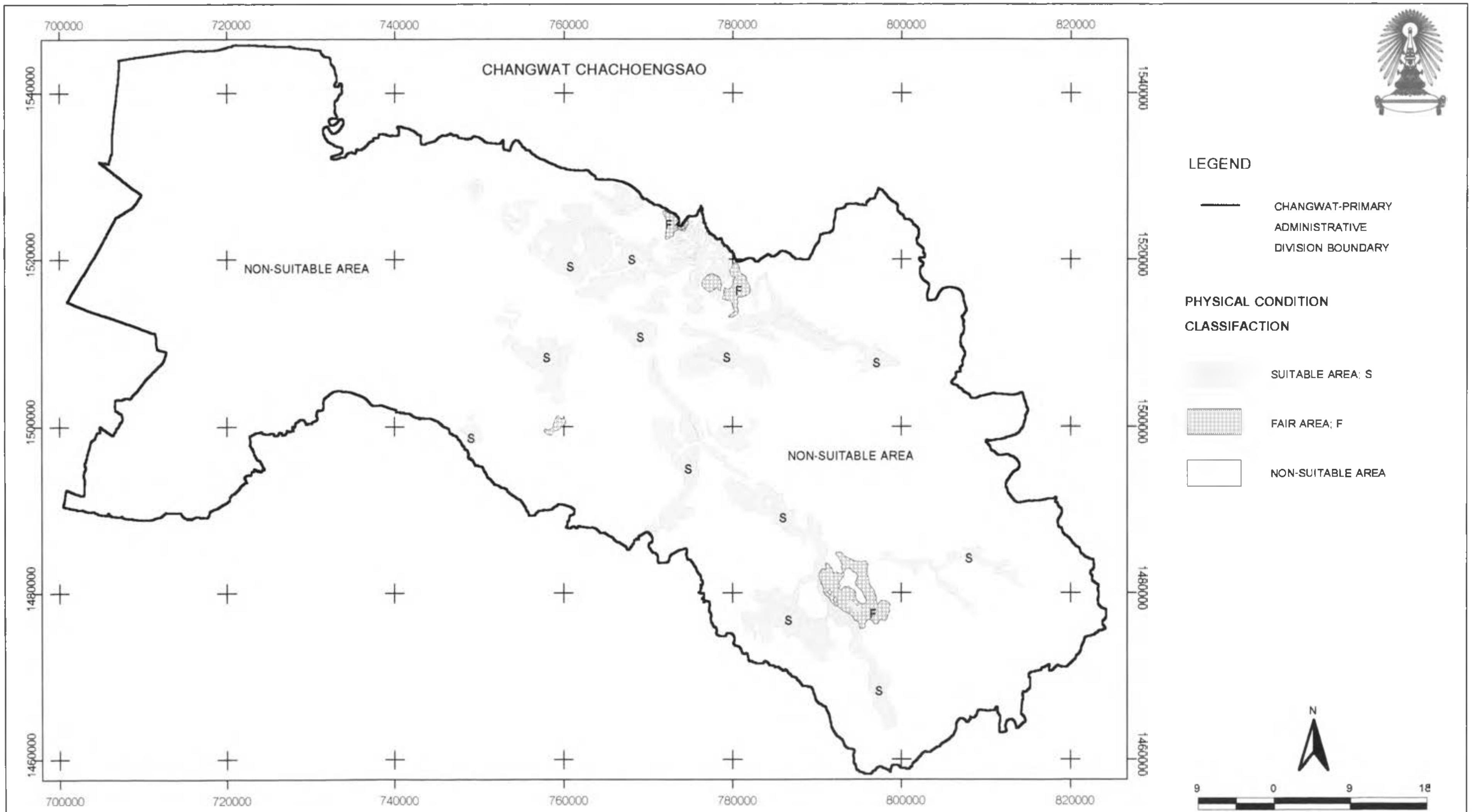

FIG. 4.1 SUITABLE PHYSICAL CONDITION MAP (SOIL MAP)

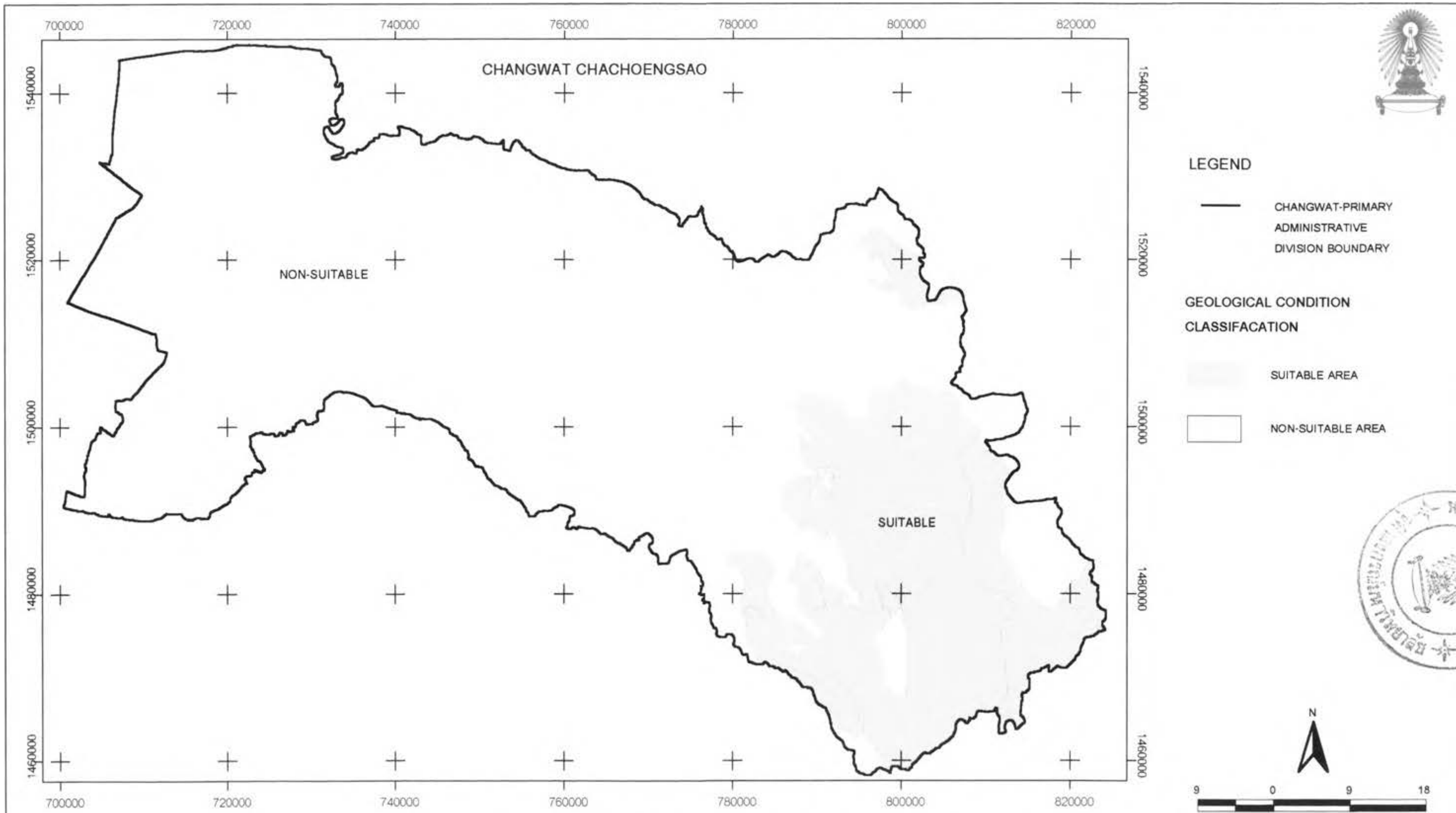

FIG. 4.2 SUITABLE GEOLOGICAL CONDITION MAP (GEOLOGICAL MAP)

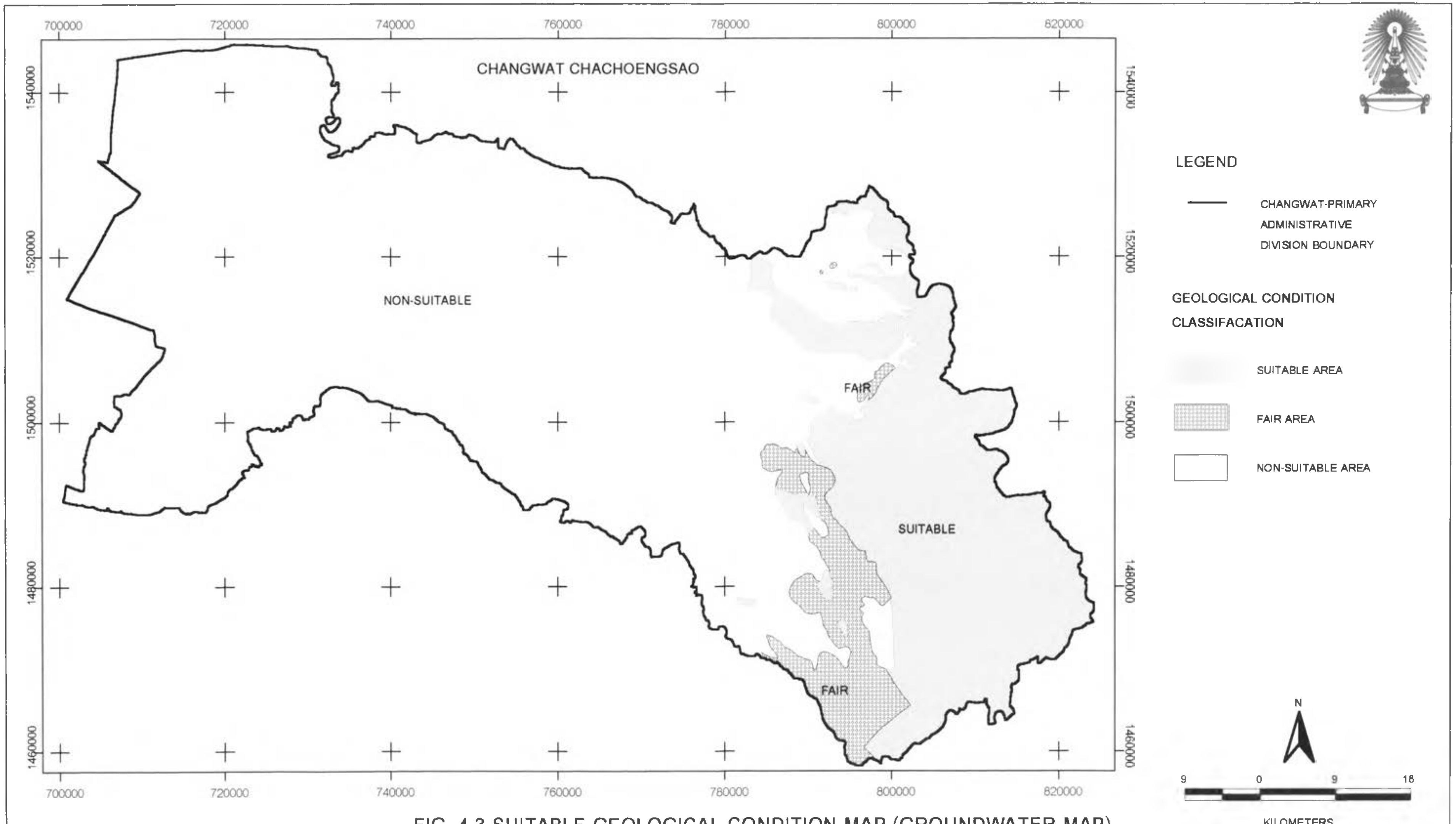

FIG. 4.3 SUITABLE GEOLOGICAL CONDITION MAP (GROUNDWATER MAP)

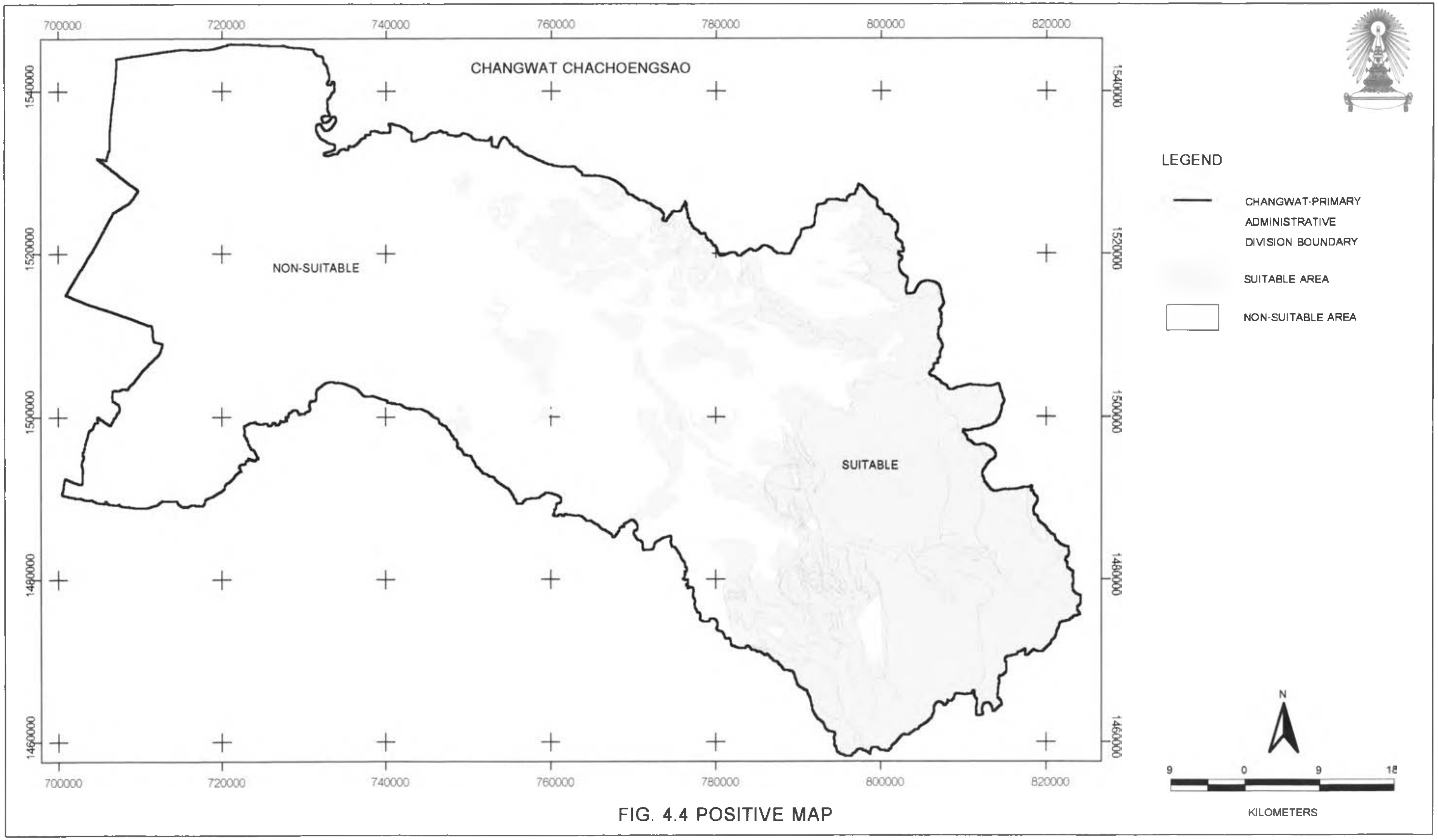

FIG. 4.4 POSITIVE MAP

4.2.2.2 Negative Mapping

All of the negative criteria shown in Table 4.4 are bounded and integrated for preparation of the negative map. Figure 4.5 shows non-suitable area for sanitary landfill.

4.2.2.3 GIS Technique

Because of suitable areas selection is regarding to environmental geology (physical) factor, i.e., topography, geology, surface water, groundwater, soil characteristic, land use, etc., the Environmental Protection Standard and limitation from Pollution Control Department and Standard of Foreign are considered.

Consequently, government organization database and modified database are integrated and analyzed using GIS technique.

ArcView GIS Version 3.1 software is used for data input and edits, data storage and retrieval, data manipulation and analysis, and data display and query. They are described as below:

1. *Data input and edit.* Data input is how to encode data in various types into GIS. The input data types, which cover graphic, attribute, and textual data can be in forms of hard copy (printed) and digital files. The graphic data can be encoded to be digital using digitization or scanning to which attribute data are linked later. The pre-processing procedures include format conversion (data structure and data media), reconstruction and generalization of data, error detection and editing, merging of points into lines and lines into polygons, edge matching, and rectification and registration.

2. *Data storage and retrieval.* The GIS data should be able to manage efficiently. Not only high efficiency in data storage and retrieval required in GIS but also data update and security should be provided.

3. *Data manipulation and analysis*. By nature, GIS data are generated as map layers. Therefore, GIS analysis functions are capable for new layer generations and also layer integration. The GIS functions cover from simple analyses to ones that use the facilities of mathematics and statistics.

4. *Data display and query*. Data display and query are functions used to show results to users. The system should be able to produce the results in hard copy form through printing media. It would also allow querying, which is on-line questioning of the database such as attribute, statistics, measurements, etc (Smith et al., 1989).

Figure 4.6 shows analytical model of potential solid waste disposal area selection using GIS technique.

From overlay technique (erase cover operation), the positive map is erase cover by the negative map. As a result, there are 17 suitable areas, including Thungphraya1 (THU1), Thungphraya2 (THU1), Kuyaimee1 (KU1), Kuyaimee2 (KU2), Ladkrathing1 (LAD1), Ladkrathing2 (LAD2), Tha Takiab1 (THA1), Tha Takiab2 (THA2), Tha Takiab3 (THA3), Klong Takrao1 (KT1), Klong Takrao2(KT2), Klong Takrao3 (KT3), Klong Takrao4 (KT4), Klong Takrao5 (KT5), Klong Takrao6 (KT6), Klong Takrao7 (KT7), Klong Takrao8(KT8) as shown in Figure.4.7.

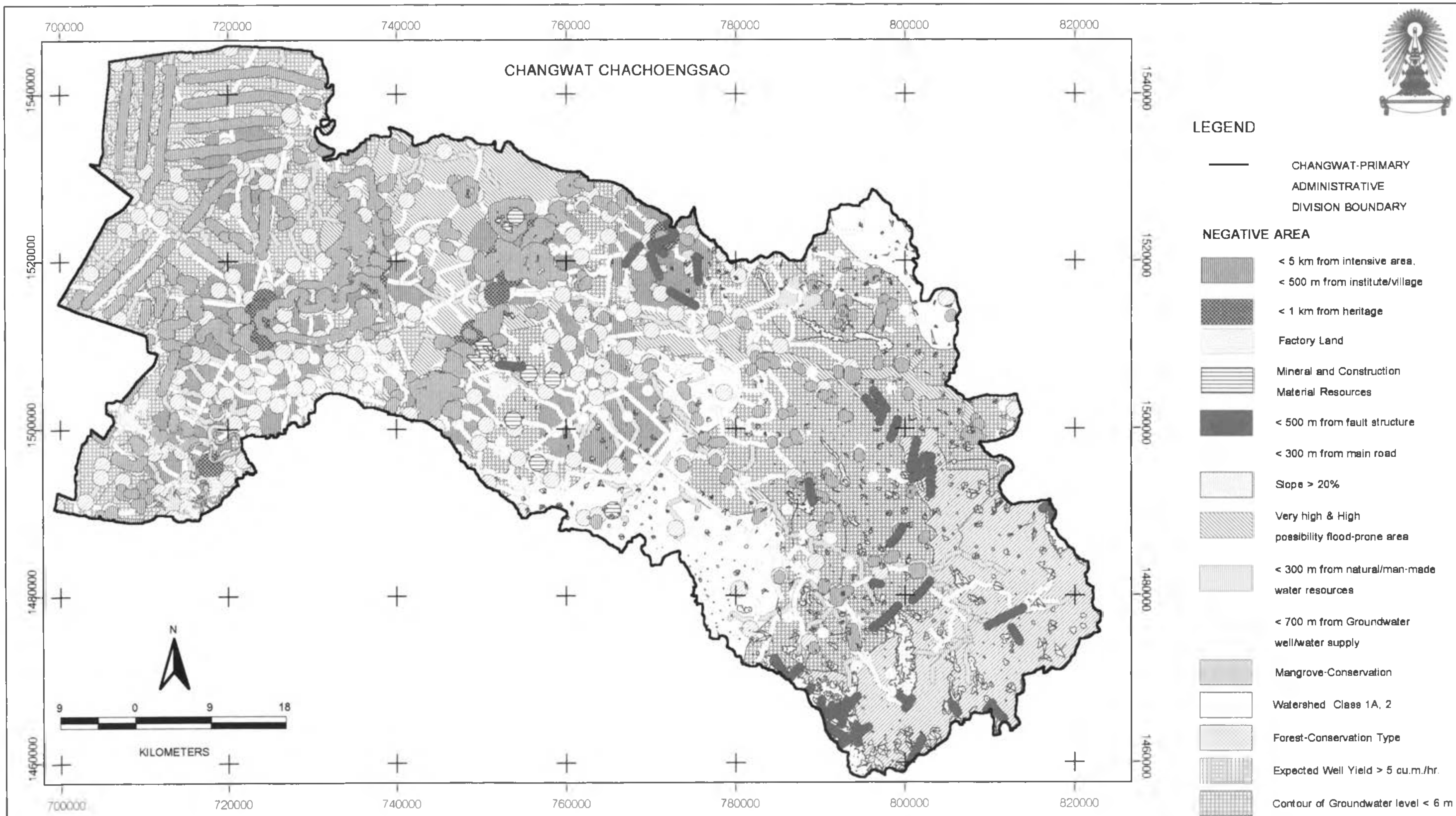

FIG. 4.5 NEGATIVE MAP

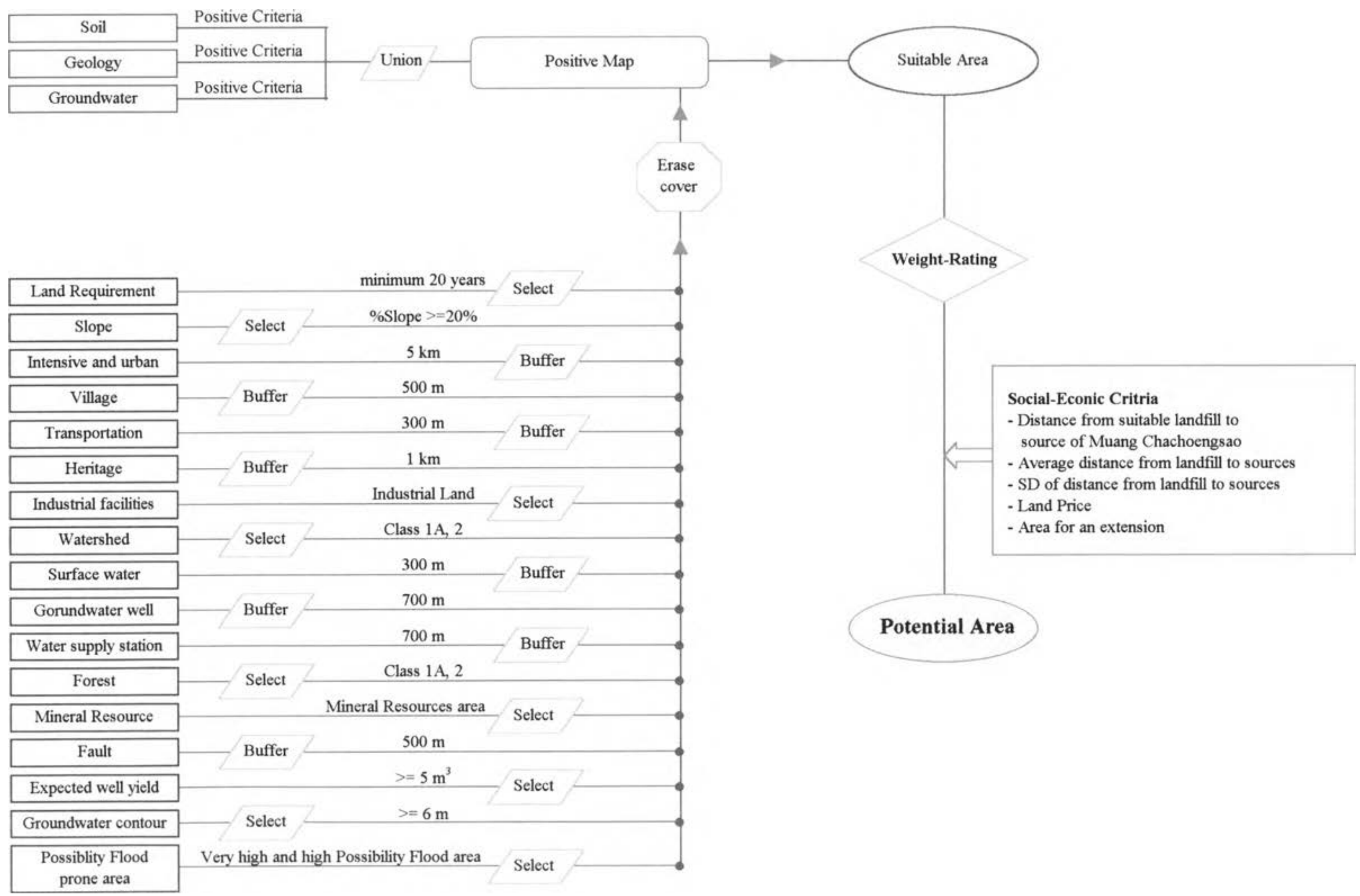

Figure 4.6 Analytical Model of Potential Solid Waste Disposal Area Selection Using GIS Technique

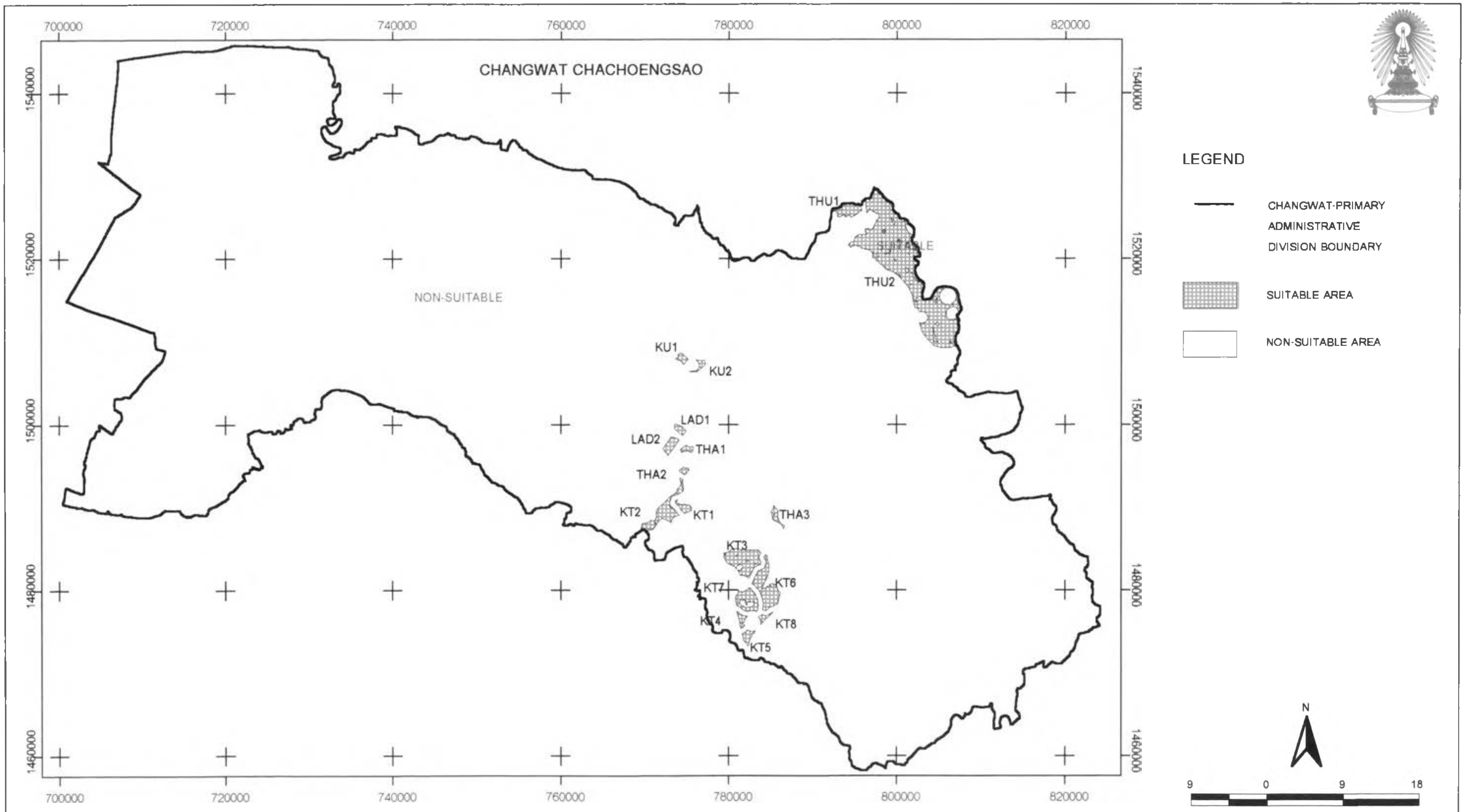

FIG. 4.7 SUITABLE AREA MAP

4.3 Potential Area Priority Using Weight-Rating System

The suitable areas for sanitary landfill are selected from and preceded by Socio-Economic criteria in order to approach the potential area priority using Weight-Rating system. A weight-rating system is based on the theory of logical combination. A weight or a measure of relative importance will be assigned each influencing factor. Each of the influencing factors is subdivided into subclasses and given index numbers called 'a rating' (Quoted by Thassanapak, 2001). For this study, a simplified formula is proposed as below equation.

$$S = W_1R_1+W_2R_2+....+W_nR_n \qquad (4.6)$$

where S = total score in each area

W = value of the important factor

R = value of subclasses of the important factor

The weight factors are assigned and directly expressed the relative important factor and then the higher number to other more important factors. For the present study, the weight of 0.4, 0.4, 0.15, and 0.05 are given to distance from suitable areas to waste origin of Muang Chachoengsao municipal (DSWMC), distance from suitable areas to waste origins of municipal/sanitary of Changwat Chachoengsao (DSWCC), land price, and area for an extension, respectively. For distance from suitable areas to waste origins of municipal/sanitary of Changwat Chachoengsao parameter is subdivided into 2 sub-parameters, namely, average of DSWCC, and standard deviation of DSWCC which their weight are 0.35, and 0.05, respectively. Table 4.6 summarizes the weight of Socio-Economic Criteria.

The Rating scale included values in an arbitrary range of 1 to 5. A value of 5 expressed the best capability. Table 4.7 summarizes rating value that is classified by 20 percentile of statistic.

Table 4.6 Summary of the Weight of Socio-Economic Parameter.

No.	Parameters/Sub-parameters	Weight Value	
		Sub-Parameter	Parameter
1	Distance from Suitable areas to Waste origin of Muang Chachoengsao Municipal (DSWMC)	-	0.4
2	Distance from Suitable areas to Waste origins of Municipal/Sanitary of Changwat Chachoengsao (DSWCC)	-	0.4
	2.1 Average of DSWCC	0.35	-
	2.2 Standard Deviation of DSWCC	0.05	-
3	Land price	-	0.15
4	Area for an extension	-	0.05
Total of weight value			1.00

Table 4.7 Summary of Rating Value (20 Percentile Interval).

Score	DSWMC	DSWCC		Land Price	Area for an Extension
		Average	SD		
	(m)	(m)	(m)	Bath/Rai	(times)
5	< 63,967.3500	< 61,333.7063	< 22,990.3323	20,000	≥ 10.16
4	≥ 63,967.3500 < 69,021.0440	≥ 61,333.7063 <67,958.1417	≥ 22,990,3323 < 23,060.8930	30,000	≥ 2.86 < 10.16
3	≥ 69,021.0440 < 81,973.5180	≥ 67,958.1417 < 81,153.7563	≥ 23,060.8930 < 23,603.4154	40,000	≥ 1.76 < 2.86
2	≥ 81,973.5180 < 89,756.5500	≥ 81,153.7563 < 88,936.7914	≥ 23.603.4154 < 26,466.8259	50,000	≥ 1.34 < 1.76
1	≥ 89,756.5500	≥ 88,936.7914	≥ 26,466.8259	-	< 1.34

Note: Each land price was defined by each score, because their land price are not varies values.

Weight Discussion

Two weight of each socio-economic parameter is the first step for discussion. Land price of Thungphraya, Kuyaimee, Ladkrathing, Tha Takiab, Klong Takrao are 20,000, 40,000, 50,000, 30,000, 40,000 Bath/Rai (Department of Land, 1996), respectively. Their land price are not different, so weight value of land price should be less than weight of DSWMC and DSWCC.

Area for an extension of each suitable area are varies from 1.20 to 109.10 times (see Appendix C-Table C.1). The areas for an extension are different, but not seriously taken into account in this study. However, in the present study, limits lifespan to at least 20 years. Thus, weight of extension area for landfill should be less than land price.

One of the objectives in this present study is to select the potential area for sanitary landfill, so, distance from the potential area to each source (DSWCC) should be the nearest. In addition to distance from the potential area to Muang Chachoengsao municipal (DSWMC) should also be the nearest. Considering with land price and area for an extension parameters weight of DSWMC and DSWCC should be given more than both of them. Besides, sum of weight of DSWMC and DSWCC should be more than half of total weight. And weights of DSWMC and DSWCC should be equal. Consequently, weights of DSWMC and DSWCC in the present study are 0.40 and 0.40 respectively.

DSWCC parameter is subdivided into two sub-parameters, namely, average of DSWCC, and standard deviation of DSWCC. That is, the mostly potential area should be the least of average of DSWCC, and standard deviation of DSWCC. The relationships between average of DSWCC, and standard deviation of DSWCC are 0.40:0.00, 0.35:0.05, 0.2:0.20, 0.05:0.35, and 0.00:0.40, respectively (Define Constant weight of DSWMC: land price: area for an extension = 0.40: 0.15: 0.05, respectively) (see Appendix C. Table C.3-C.7). Standard deviation of DSWCC has a higher of weight, priority of potential area will not be reasonable. Consequently, weights of average of DSWCC and standard deviation of DSWCC are 0.35 and 0.05, respectively.

Weight of DSWMC and DSWCC are 0.40 and 0.40, respectively. Sum of weight of land price and area for an extension is 0.20. Then, the ratio between land price and area for an extension are 0.15:0.05, 1.00:1.00, 0.05:0.15, respectively are done. Priority potential areas (Define constant weight of DSWMC: average of DSWCC: standard deviation of DSWCC = 0.4:0.35:0.05, respectively) are not different (see Table C.8- Table C.10). Weight of land price and area for an extension are 0.15 and 0.05, respectively.

Consequently, the weight of 0.40, 0.35, 0.05, 0.15, and 0.05 are given to DSWMC, average of DSWCC, standard deviation of DSWCC, land price, and area for an extension, respectively.

Rating Discussion

With respect to the determination of rating values, 20 of Percentile, and 25 Percentile of Statistic are used for rating group interval. In the present study, 20 of Percentile statistic is used for rating values interval because of distinct total score of each suitable. If use less than 20 percentile separate score interval, distinct priority potential areas are not different from 20 percentile. Consequently, 20 of Percentile statistic is used for rating values interval for scoring each socio-economic parameter. For rating value interval are separated by 25 percentile as presented in Appendix C-Table C.11.

In addition to values of each socio-economic criteria of each suitable area for Weight-Rating Calculation are summarized in Appendix C-Table C.1. For Appendix C- Table C.2 summarizes distance of each suitable area to each waste origin of municipal/sanitary in Changwat Chachoengsao. Figure C.1 shows various routes from the suitable area to waste origins of municipal/sanitary in Changwat Chachoengsao.

After Weight-Rating System Calculation was done, priority potential areas in the present study have been described in ascending order. There are 4.35 points of Lad Krathing2, 4.35 points of Kuyaimee1, 4.30 points of Kuyaimee2, 4.20 points of Thatakiab2, 3.85 points of Ladkrathing1, 3.85 points of Klongtakrao2, 3.75 points of Tha Takiab1, 3.20 points of Klong Takrao6, 3.15 points of Thatakiab3, 3.10 points of Klong Takrao1, 2.45 points of Klong Takrao3, 2.35 points of Klong Takrao7, 2.25 points of Klong Takrao8, 1.80 points of Thungphraya2, 1.75 points of Thungphraya1, 1.55 points of Klong Takrao5, 1.50 points of Klong Takrao4. The potential area priorities are presented in Table 4.8 and Figure 4.8.

4.4 Field Observation

After finished from potential area priority, some potential areas are selected for field observation. They are described as below.

THA TAKIAB 1

Grid Reference: 775890E, 1497015N

This area is economic forest of Ladkrathing sub-district, Ministry of Agriculture and Cooperation that is used for Eucalyptus plantation. Figure 4.9 shows general characteristic of this area. Besides, this location is drilled by hand auger about 1.50 meters of the depth, because of refusal (hard sediments). Figure 4.10 shows general characteristic of soil. For soil profile description of Tha Takiab 1 is presented in Appendix D-Table D.1.

THA TAKIAB 2

Grid Reference: 774284E, 1494243N

This area is same above that is economic forest of Ladkrathing sub-district, Ministry of Agriculture and Cooperation that is used for Eucalyptus plantation.

LADKRATHING 1

Grid Reference: 773918E, 1498933N

This site, which is not far from Tha Takiab 1 is used for paddy field. During field observation, activity of paddy field is finished (28 March 02). Figure 4.11 shows general characteristic of this area. And this area is drilled by hand auger about 2.50 meters of the depth, because of refusal same above (hard sediments). Besides, in this borehole,

Table 4.8 Priority of Potential Area

PRIORITY	LOCATION	SCORE OF EACH SOCIO-ECONOMIC CRITERIA					SUM OF RATING	SUM OF WEIGHTING
		DSWMC WEIGHT: 0.40	Average of DSWCC WEIGHT: 0.35	SD of DSWCC WEIGHT: 0.05	Price of Land WEIGHT: 0.15	Area for an Extension WEIGHT: 0.05		
1	**LAD KRATHING2**	**5**	**5**	**2**	**2**	**4**	**13**	**4.35**
1	**KUYAIMEE1**	**5**	**5**	**1**	**3**	**2**	**11**	**4.35**
2	KUYAIMEE2	5	5	1	3	1	10	4.30
3	THATAKIAB2	5	4	3	4	1	12	4.20
4	LADKRATHING1	4	5	2	2	2	11	3.85
4	KLONGTAKRAO2	4	4	3	3	5	15	3.85
5	THA TAKIAB1	4	4	2	4	1	11	3.75
6	KLONG TAKRAO6	3	3	5	3	5	16	3.20
7	THATAKIAB3	3	3	3	4	3	13	3.15
8	KLONG TAKRAO1	3	3	5	3	3	14	3.10
9	KLONG TAKRAO3	2	2	5	3	5	15	2.45
10	KLONG TAKRAO7	2	2	4	3	4	13	2.35
11	KLONG TAKRAO8	2	2	5	3	1	11	2.25
12	THUNGPHRAYA2	1	1	1	5	5	12	1.80
13	THUNGPHRAYA1	1	1	1	5	4	11	1.75
14	KLONG TAKRAO5	1	1	4	3	3	11	1.55
15	KLONG TAKRAO4	1	1	4	3	2	10	1.50

Remark Use Percentile 0.2, 0.4, 0.6, 0.8 for separated score level

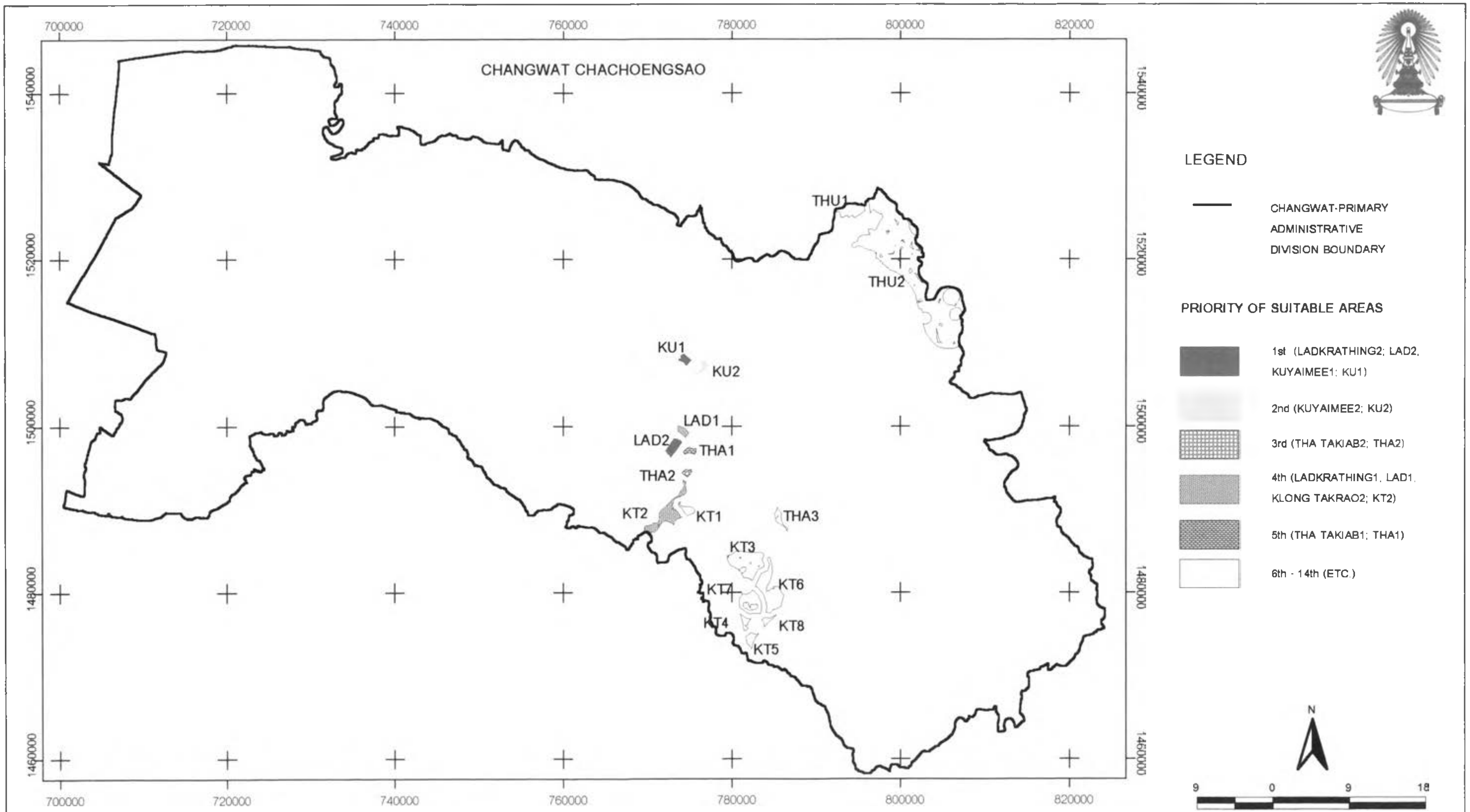

FIG. 4.8 POTENTIAL MAP

FIG. 4.9 THA TAKIAB 1 SITE.

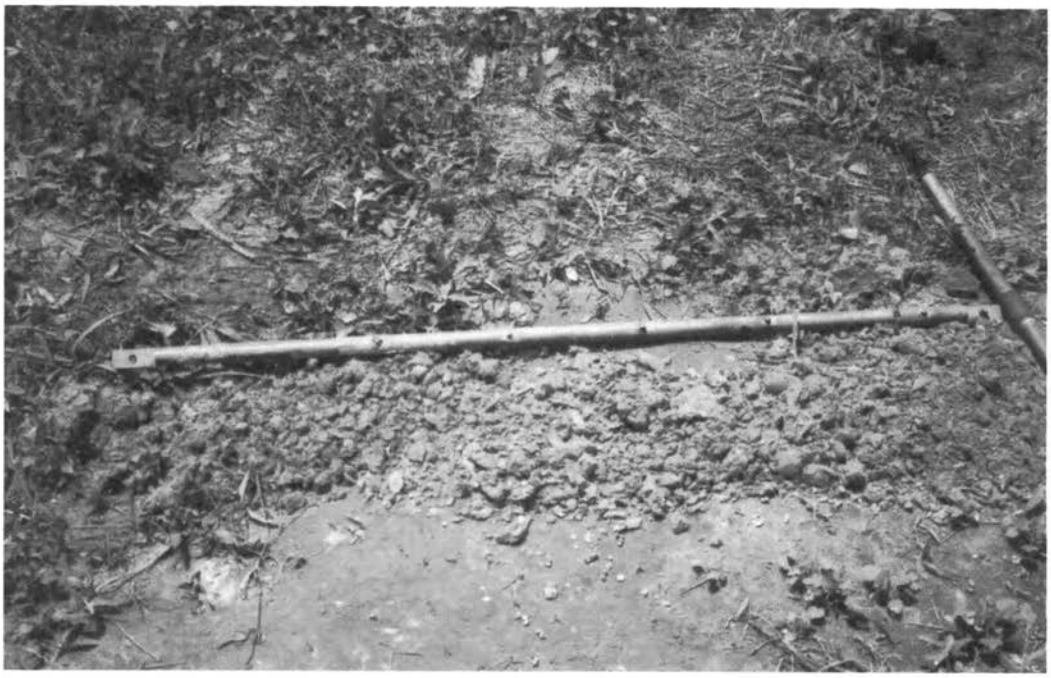

FIG. 4.10 SOIL CHARACTERISTIC AT THA TAKIAB 1 SITE

groundwater table can be found at depth about 2.00 meter from ground surface. Figure 4.12 shows general characteristic of soil. For soil profile description of Lad Krathing 1 is presented in Appendix D-Table D.2.

LADKRATHING 2

Grid Reference: 773840E, 1498848N

This site far from Ladkrating 1 site about 50 meters is used for sugar cane. This site wasn't drilled. General characteristic of this area can seen in Figure 4.13

KUYAIMEE 1

Grid Reference: 775332E, 1507842N

Landuse of this area includes mixed field crops, Eucalyptus plantation, and Para rubber. Figure 4.14 shows general characteristic of this area.

KUYAIMEE 2

Grid Reference: 776255E, 1508007N

Landuse of this area is same above (mixed field crops, Eucalyptus plantation, and Para rubber). Figure 4.15 shows general characteristic of this area. For this site can be found Ban Nong Yang reservoir at Southwest of this site. If this site is selected for landfill, landfill design should be concerned contamination. Figure 4.16 shows characteristic of Ban Nong Yang reservoir.

From soil profile description of Hole No.1 (Tha Takiab 1), and No.2 (Ladkrathing 1), both sites will be investigated in details for sanitary landfill construction. Area Method is appropriate operation for sanitary landfill because of groundwater table level is found at depth 2.00 meters below ground surface of Hole No.2.

FIG. 4.11 LAD KRATHING 1 SITE

FIG. 4.12 SOIL CHARACTERISTIC AT LAD KRATHING 1 SITE

FIG. 4.13 LAD KRATHING 2 SITE

FIG. 4.14 KUYAIMEE 1 SITE

FIG. 4.15 KUYAIMEE 2 SITE

(a)

(b)

FIG. 4.16 BAN NONG YANG RESERVOIR